By the same Authors

LATHE DEVICES: THEIR CONSTRUCTION AND USE

WORKSHOP EQUIPMENT

Its Design, Construction and Use

by

IAN BRADLEY

and

NORMAN F. HALLOWS
M.A. (OXON.)

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PREFACE

ALTHOUGH at the time of writing workshop equipment is difficult to acquire, even in happier times fitting out a workshop was far from easy, not because there was any lack of tools, but so often owing to the difficulty of finding the type of tool sought, if it existed, quite apart from its cost.

This at times led enthusiasts to plan and make their own tools and small machine tools, and in this they were nobly helped by enterprising firms who supplied castings and machined parts.

Moreover, in these days of submerged craftsmanship, mass production and selective assembly, the true mechanic can, nevertheless, by the exercise of his skill and patience construct, in many instances, a better tool than he can buy, except, perhaps, in the exclusive precision market which is beyond his financial reach. Again, he seeks no tools to feed the mass production mill, but rather those to do his single jobs truly and in response to careful keep and kindly use.

With these facts in mind, depressing or encouraging according to the viewpoint, we have drawn on our experience for those seeking to acquire the tools most useful to them in their craft or better still, perhaps, we may have given some little encouragement in this book and elsewhere to those who would make their own tools, or who delight in making better use of those they have.

We are greatly indebted to the Proprietors of the *Model Engineer* for their permission to publish extracts from articles, which appeared in that Journal, describing a Hacksaw Machine, a Rule Holder, and their Drilling Machine of special design.

We would also like to express our thanks to the following Firms who have kindly supplied us with photographs and blocks for reproduction in this book: The Hymatic Engineering Co. Ltd.; Messrs. Lister & Co. Ltd.; The Myford Engineering Co. Ltd.; The Norman Engineering Co. Ltd.; Mr G. P. Potts; Messrs. J. A Prestwich & Co. Ltd.; The Skefko Ball Bearing Co. Ltd.; Messrs. T. Senior; and Messrs. S. Wolf & Co. Ltd.

I. B.
N. H.

CONTENTS

CHAPTER I

WORKSHOP PLANNING

The Design of Workshop Buildings. Lighting. Heating. Ventilation. Adapted Buildings. Location of Machine Tools. Location and Construction of Work Benches. Storage of Equipment. The Home Workshop.

THE primary consideration is whether the workshop is to be a self-contained unit, or is to form a part of a main building such as a dwelling house.

The former condition will probably apply generally to the small professional organization, whilst the latter is chiefly of interest to amateurs, with the possible exception of a commercial firm, wishing to install an experimental shop away from their main works but incorporated with their central office premises.

Nevertheless, the amateur may require a self-contained detached workshop, if he intends to undertake work needing more space than a small indoor shop can provide.

In the general interest, therefore, it is proposed to consider in the first place the provision of a unit building type of workshop.

This class of building can be divided into two categories; the first includes those specifically designed for the purpose, and the second those which have to be adapted to suit. In the case of the former, within the limits imposed by cost, all important constructional features can be embodied in the design, but with the latter some structural alterations may be necessary to attain a satisfactory result.

The Design of Workshop Buildings

In the case of the commercial shop, some of the floor space may have to be devoted to offices and stores, but the amateur is not concerned with this provision, and, apart from some simple stores arrangements, he can devote the whole of the available space to the workshop proper.

In every instance, three points need careful consideration, namely, Lighting, Heating and Ventilation; the first because upon it depends the efficiency and some of the comfort of working; the second for the reason that unless the heating is adequate the attendant discomfort will militate against doing good work, and, in addition, materials and machine tools may suffer much damage from rusting due to atmospheric humidity. In the professional shop, however, adequate heating is obligatory under the Factories Act.

As to the third point, ventilation, although this is important for promoting comfort, particularly in hot weather, it is specially necessary whenever work involving the production of fumes is undertaken, such as brazing, case-hardening and spray-painting.

In fact, if much of this work is to be undertaken, it is advisable to make special provision for ventilating the part of the shop concerned.

This matter will be discussed later in the appropriate section of this book.

Lighting

In the case of a new building, it will be possible to make proper use of daylight by means of adequate roof-lighting and by the provision of windows in the walls of the building.

These windows should have a north aspect whenever possible.

At one time, it was the practice to equip workshops with saw-tooth roofs, and here again the more obtuse-angled glazed roof slope was set, whenever possible, facing north.

Latterly, however, the tendency has been to revert to the practice of building roofs of more normal angularity, and in the case of span roofs, the glass is now set in both sides of the ridge and in close proximity to it.

This practice has the advantage of providing more uniform lighting, especially in shops where overhead line shafting is used to drive the machines.

In industry to-day, the use of fluorescent lighting is increasing, and there can be no doubt that it has great advantages, principally by reason of its similarity to daylight, and also owing to its comparative freedom from shadow formation.

However, the high cost of installation may preclude its general use in the small shop, though the adoption of single units may be considered if the expense seems warranted.

In a small workshop, perhaps the best plan is to dispense

with general lighting and to light the machines and work benches individually.

The normal dispersion of this light will usually be sufficient to provide for the general lighting of the shop.

A wide choice of equipment for individual lighting is available, but the type selected should have adequate mechanical strength, proper protection for the bulb, and should be capable of universal positioning as required.

In this connection, steady progress has been made in adapting low-voltage lighting for use on machine tools.

This installation comprises a small transformer connected to the mains, which serves a low-voltage bulb, usually of 12 volts rating.

As the whole of the moveable part of the equipment is of small size, it has the advantage of taking up but little space on the machine.

This development resulted from the industrial demand for a shock-proof inspection light, as the use of the mains voltage for lighting machines had proved unsatisfactory, owing possibly to lack of proper inspection and maintenance.

So far as standard lighting fittings are concerned, it can be affirmed that, in the long run, the best obtainable are the cheapest, for inexpensive equipment may deteriorate rapidly and be troublesome when replacements have to be made.

Heating

When a comprehensive heating system is planned to include the installation of elaborate equipment, expert advice may be sought with advantage.

Again, in the case of a commercial undertaking, where the maintenance of a definite temperature in the workshop is obligatory, as there are so many complex factors affecting the final result it is advisable to obtain expert technical guidance.

For the small amateur shop, however, some form of slow-combustion stove heating may be found adequate to provide sufficient warmth during cold weather, and to prevent the air from becoming damp, and so causing rusting. In addition, the shop will be comfortable and always ready for immediate use, as the oil in the machine bearings will not be cold and viscid.

The question of heating on a small scale will be further considered in connection with the Home Workshop.

It should be emphasized that, whatever the form of artificial heating employed, the products of combustion should not be allowed to escape into the shop as they contribute largely to the formation of rust.

Apart from the initial expense of installation, hot-water heating by means of radiators fed from a central boiler is the ideal system for all classes of workshops. In some instances, it may be advantageous to extend the central heating installation of a main building to include an adjoining workshop.

Ventilation

This is a problem which in part depends on the size and scope of the workshop; for at one end of the scale is the shop which can be ventilated satisfactorily merely by opening windows and doors, while at the other extreme are shops where it is obligatory to maintain a definite temperature, and to provide adequate ventilation to remove noxious fumes.

At the outset, it will be apparent that the problems relating to heating and ventilation are interdependent, and that in many instances expert guidance is advisable when planning and installing these systems.

Adapted Buildings

Under this heading are garages, independent of or attached to houses, outbuildings such as are found on farms, garden sheds, and other buildings considered suitable for adaptation as workshops.

In the first place, it is essential that the building selected be made weatherproof, and also that it should have sufficient structural strength to support any lineshafting or machine tools that are installed.

It may be necessary to go to some length to ensure that these conditions are fulfilled, and, moreover, relaying may be required to obtain a strong and level floor.

In nearly every case, the lighting will be found inadequate, owing to the smallness of the windows and the absence of top-lighting.

When fitting roof lights, it is an advantage to place them over the main machine tools and fitting benches, and care should be taken to avoid the lineshafting throwing shadows on the machines below, as it is tiring to the eyes to have the shadow of a revolving pulley playing on the work during machining.

Roof lights should be well-constructed, and, if made to open, must be designed to close properly and exclude rain.

Although daylight is the best illuminant in the workshop, the additional use of artificial light is often required where structural alterations to promote the ingress of daylight are inadequate.

As previously mentioned, heating and ventilation will also require careful consideration and skilled planning.

Location of Machine Tools

As has already been emphasized, machines should, if possible, be placed directly under top-lights and with their backs close to windows in order to make the greatest use of the daylight available.

If there is sufficient room in the shop to allow access to the back of the machines, this is an advantage when cleaning is undertaken, but unfortunately the small shop seldom has this extra space to spare.

When planning the machine tool installation, space should be allotted for any additional tools that may be required at a later date, for few amateurs or small professional workers buy the whole of their tool equipment at one time.

These advance preparations are facilitated by machine tool manufacturers, who supply particulars and dimensions of lathes, drilling machines and other tools suitable for use in the small workshop.

This planning in advance must also take into account the positioning of the lineshafting, which should ensure that the counter-shaft can be placed at a sufficient distance from the line-shaft to provide an efficient drive.

Short drives with flat belts promote belt slip, which can only be overcome by running the belt abnormally tight, and thus causing undue wear of belts, shafts and bearings.

On the other hand, V belt drives are normally installed with short drive centre distances, so this factor may also be considered when planning and equipping the workshop.

Location and Construction of Work Benches

As in the case of machine tools, work benches should be placed so that the light falls on the work from in front and also from above; that is to say, their position should be in front of windows and under top-lights.

Two benches at least will be required, one for fitting and hand work, and the other for laying-out partly finished work, for marking-out, and the final assembly of parts.

The latter bench need not be heavily constructed, unless weighty components are to be handled, but the work bench must be strongly made and sufficiently rigid to withstand the thrusts imposed by filing and sawing.

The frame of this bench should be made of 4 in. by 2 in. quartering, and the legs of not less than 3 in. square material, whilst the top, to which the vice is fixed, should be made of 9 in. by 2 in. planks. The vice should be mounted directly over one of the bench legs, which must be firmly fixed to the floor, whilst the bench itself may with advantage be secured to the fabric of the building.

Storage of Equipment

To prevent damage and for the sake of orderliness, it will be apparent that some means of storing the tools and small equipment is essential.

This storage space is usually provided in cupboards and drawers and on shelves, but the two former should be used to house fine tools and machine tool accessories to prevent exposure to dust, and possibly the formation of rust due to rapid changes of temperature.

Cupboard shelves should be covered with celluloid sheets or other such material, to prevent rusting of the tools from contact with the wood.

Tools such as files, pliers and hammers are usually kept in racks, from which they may be readily withdrawn for use.

Drills and reamers are best kept vertically in pads or racks, which should indicate clearly the size of the tools contained.

Screwing tackle may be housed either in individual boxes by sets, with a space for each tap and die to prevent damage, or taps alone may be kept vertically in racks and their corresponding dies stored in boxes.

The Home Workshop

A part of a house or a single room often forms the workshop of the amateur or the small professional worker.

The room may be entirely devoted to the workshop, or if there is sufficient space, it may in addition be used as a study or sitting room.

The latter combination offers certain advantages, such as general comfort as well as adequate heating, lighting and ventilation.

Moreover, a comfortable workshop near-at-hand usually means more work done, for it will be seldom worth while in cold weather to heat the shop specially for a brief spell of work, but rather to await an accumulation of work; with the result that much intermittent working time is lost.

The more continuous heating used in the sitting room also obviates the necessity of greasing tools and machines to prevent the formation of rust, so that for most work there is no need to don overalls or even to get the hands greasy.

For the sake of comfort, a carpet may well be laid on the floor, but at the workshop end of the room linoleum and mats are perhaps preferable, for the latter can be shaken and brushed outside to remove chips.

To prevent machine swarf reaching the floor, it may at times be necessary to confine the chips to the bench top by means of a sheet of cardboard temporarily fixed in position. If chips and swarf are regularly swept up and are not trodden about the room, the task of those responsible for the cleaning will not be made more difficult.

The fitting of curtains over doors and windows, besides giving an appearance of comfort, also helps to maintain the temperature of the room, by excluding draughts and lessening the cooling effect of the windows in cold weather.

Heating and Rust Prevention.—As the method of heating the room and rust formation are so closely connected, it may be opportune here to consider the process by which rust is formed, and the means required to prevent it.

Rusting, in general, is the process of surface corrosion of ferrous metals by the action of the gases in the atmosphere when dissolved in water.

These gases, particularly oxygen and carbon dioxide, although always present in the air of the workshop, have no appreciable action on metallic surfaces in the absence of water. For our purpose, the water necessary to promote rusting comes from the water vapour present in the air, when it is condensed on the metal and deposited in the form of dew.

At any given temperature the air can carry a certain known amount of water vapour, but, if the temperature of the air falls,

a lesser amount only can be carried, with the result that the surplus water vapour is deposited on surrounding objects in the form of dew, or in more extreme cases atmospheric fog is formed.

On the other hand, if the temperature remains constant and more water vapour is introduced into the room, as by the burning of an oil stove or a coke stove without a proper flue, condensation of this added water vapour will be liable to occur, unless, of course, at the same time the temperature of the room and its contents is correspondingly raised.

In the same way, if warm air from without is allowed to enter a cold room, condensation may take place on articles which are below the temperature of the incoming air.

An example of this is seen when a glass of cold well water is exposed to the air on a warm day; the warm air is unable to retain its high water-vapour content when cooled by contact with the cold glass, and dew is formed.

Alternatively, the warm moisture-laden breath is seen to condense on a cold day or when a cold surface is breathed upon.

This rough test may be used with advantage to ascertain whether the condition of the air in the workshop favours condensation. Or again, for those so inclined, an accurate estimate of the degree of saturation of the air can be made by using a direct-reading hygrometer, or by observing a wet- and dry-bulb thermometer.

If the house is equipped with central heating and the workshop is fitted with radiators, the atmosphere can be kept always warm and dry, and rusting will not occur.

A small slow-combustion anthracite stove is very convenient for heating the workshop, as it can be lighted either as occasion requires, or used continually in cold weather with but little expenditure of fuel.

Some makes of anthracite stoves are very economical in use, but a proper flue must be fitted to keep the fumes and water vapour formed from reaching the air of the room.

Coke stoves and open fireplaces are more troublesome to operate owing to the more frequent stoking required.

If the power rate is low, electric heaters may be considered, as they have the advantage of not producing fumes or water vapour and require no flue, but although they are clean and convenient to operate, especially for intermittent heating, they are not always suitable for long periods of continuous use.

Oil heating stoves, which have no ventilating flue, pass large quantities of water vapour into the room as a result of the combustion of the fuel, and are, therefore, apt to promote rusting during cold weather.

In practice, therefore, rusting may be prevented by maintaining an adequate temperature in the workshop, and, if the heating is discontinuous, every effort should be made to prevent heat loss during the periods when the source of artificial heat is not in use.

To this end, thick outside walls are advisable and, as already mentioned, draughts should be excluded and cooling by window surfaces prevented by using heavy curtains.

Additional care should be taken in cold weather when using gas burners and brazing lamps, as these add large quantities of water vapour to the air.

The fumes which arise when using some soldering fluids are a potent source of metallic corrosion, and the remedy here is free ventilation or the use for this purpose of a room unconnected with the workshop.

If satisfactory heating cannot be arranged and rusting is apt to occur, bright steel and iron surfaces should be coated with oil or grease, but, as these are not always effective, special compounds with a lanoline base, such as Houghton's Rustveto, are more suitable by reason of their low permeability and surface tension.

As an additional precaution, machine tools may be covered with sheets of waxed paper, over which a cover or blanket is placed to delay the ingress of cold air.

Lighting.—As far as possible, the best use should be made of the daylight available in the room, and the benches and machine tools should be sited with this in view.

The best lighted part of the room should be accorded to the fitting bench, as daylight is preferable for this work, whereas supplementary artificial lighting is adequate for operating machine tools.

It is essential that the light source, presumably an electric bulb, should be freely movable, in order that an adequate intensity of illumination may be brought to bear at will on any particular place, or in relation to any machining operation. For this purpose the Terry Anglepoise lamp stand is excellent, for the light source has universal movement over a wide range

at a touch of the hand, and, moreover, the light does not tend to change its position after setting.

If two of these lamp stands are used, a compact workshop can be adequately lighted without having to move the lamps themselves.

As previously mentioned, tubular lighting is more expensive to install, but it is coming into more general use by virtue of its low current consumption and the character of the light, which is akin to daylight and is free from undue shadow formation.

Reduction of Noise.—The creation of noise, although inseparable in some degree from normal workshop procedure, can be greatly modified by careful planning.

As this is a matter of some importance in flats and in relation to adjoining houses and rooms immediately below, every care should be taken to render the indoor workshop quiet in operation, quite apart from the user's enhanced comfort obtained thereby.

In the first place, the floor should be of sound construction, and, if necessary, it should be strengthened to bear the load imposed. Bench legs and machine tool stands should if possible be supported on the joists, and, to deaden noise, the floor may be covered with linoleum, carpets, or rugs, according to the character of the work undertaken.

Electric motors necessarily make some noise in operation, but those fitted with plain bearings and a good lubrication system usually run more quietly than other types.

The motor should be attached to a rigid base, and, where noise is apt to be transmitted to other parts of the building, it may with advantage be mounted on thick felt or rubber pads.

Some belt drives are unnecessarily noisy, but this may in part be overcome by fitting a better form of belt fastening, such as that described in Chapter IV.

For quiet and satisfactory power transmission, the endless V belt drive is unsurpassed.

Correct balancing of rotating parts helps to eliminate noise, and, as machines are usually quieter when running at slow speed, unnecessarily high speeds should be avoided.

Storage of Tools.—When the workshop is also used as a sitting room, there is no need to spoil its appearance by a visible array of dust-collecting tools in racks and on the walls,

Rather, in this sort of workshop should all tools be kept in drawers and cabinets, where they are out-of-sight and protected from damage but readily available when required.

If, in addition, the machine tools are protected from dust by well-made fabric covers, the appearance of tidiness and comfort in the room will be maintained.

The music cabinet is a very convenient form of chest-of-drawers for housing tools, for the drawers themselves, some six in number, being large but shallow, are suitable for storing tools such as files in a single layer, thus preventing damage but at the same time affording easy access.

Miniature chests-of-drawers, such as the so-called Wellington chest, are most useful for storing tools and accessories, and a dental instrumental cabinet is excellent for housing the smaller and finer tools.

Where storage shelves are required, a glass-fronted book-case or china cabinet is both useful and decorative.

When fine tools and other accessories are stored in a cabinet or chest-of-drawers, and, due to lack of proper heating rusting is apt to occur, the tools should be prevented from making contact with the wood by covering it with some impervious material such as sheet celluloid.

In addition, a plan sometimes adopted in the case of gun cabinets may be useful: a small electric light bulb, fitted within the cabinet, is kept burning continuously in cold weather to keep the air warm and so prevent condensation.

Metal Heating Processes.—In addition to regular mechanical work, some provision must be made for carrying out heating processes such as soldering, brazing, hardening, tempering, annealing and case-hardening.

As in some circumstances, particularly when the heating of the workshop is inadequate, the fumes and water vapour generated in this way may be highly detrimental, it is better that this work should be done on a small scale only in the workshop, or better still, perhaps, that another room should be used for the purpose.

The anthracite stove, however, is convenient for hardening and case-hardening, if precautions are taken against overheating the work.

If the workshop is supplied with gas, a Bunsen burner or a gas blow-pipe will be found useful and perhaps adequate for most purposes.

Woodwork.—If care is exercised, woodwork can be undertaken without in any way making the workshop untidy.

When sawing, newspapers should be arranged to catch the sawdust and protect the floor, and, when planing, chips should as far as possible be prevented from falling on the floor, by clearing the shavings from the plane as they are formed and depositing them in the rubbish box.

Care of the Workshop.—If only for the sake of comfort, tidiness is desirable in the workshop, particularly when, in addition, it is used as a sitting-room.

If, as already mentioned, screens and chip trays are used, the floor can be kept clean and free from swarf, while neat covers on the machines not in use will guard against the ingress of dust and abrasive material, and will in no way mar the general appearance of the room.

When grinding tools, a cardboard screen will serve to catch the abrasive dust, which should be removed from the bench top with a brush, kept apart, and used only for this purpose.

At the end of the day's work, the workshop should be left clean and tidy, and all tools should be returned to their places ready for future use.

CHAPTER II

MEASURING INSTRUMENTS AND SMALL TOOLS

Rules. Micrometers. The Dial Test Indicator. Squares. The Protractor. Callipers. Gauges. The Surface Plate and Accessories. Clamps. The Scriber. Punches. The Straight Edge.

WHEN acquiring fine tools for engineering use, it should be borne in mind that those of high quality will give the best service owing to their extreme accuracy and good wearing qualities, and, as these devices are for the most part concerned either directly or indirectly with exact measurement, the importance of their accuracy will be readily understood.

Furthermore, when using these precision instruments a satisfaction will be experienced that is lacking when those of lower grade are employed.

Rules

The simplest form of device used for making direct measurements is the rule, which can be obtained in a large number of sizes and with a variety of graduations.

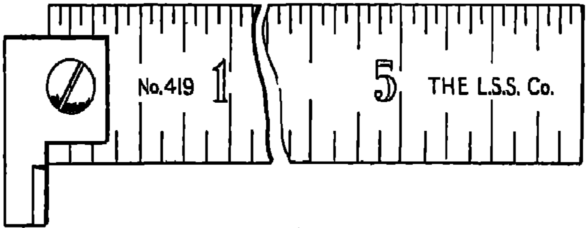

FIG. 1.—Hook Rule.

Tempered steel rules are to be preferred owing to their good wearing and rust-resisting qualities, and, although fine degrees of graduation are essential on one or more edges, coarser divisions should also be provided to facilitate making measurements of larger fractions.

For measuring the length or thickness of materials the *Hook Rule*, shown in Fig. 1, will be found convenient and conducive to accuracy, whilst for measurements of depth a simple form of *Depth Gauge* is made by fitting a sliding member to the rule, as illustrated in Fig. 2.

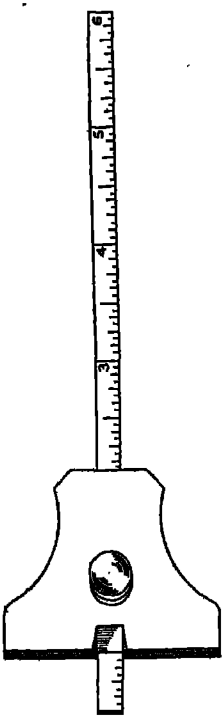

Fig. 2.—Depth Gauge.

To use the gauge, the slide is held in contact with the work, and, when the lower end of the rule has been engaged with the bottom of the hole or recess, the slide is clamped and the depth is read on the rule which is graduated in 1/64 in. and 1/100 in.

Where a rule is used for scribing parallel lines on a cylindrical part, it may be held in two clamps in order to maintain it in parallel alignment with the long axis of the work, thus forming a *Key-Seat Rule* as depicted in Fig. 3.

For fine and delicate work and also for making measurements in a confined space, the form of rule shown in Fig. 4 will be found convenient; here, a *Set of Short Rules* is provided ranging from ¼ in. to 1 in. in length, and any one of these can be fitted to the handle as required and retained in place by the screw-operated clamp.

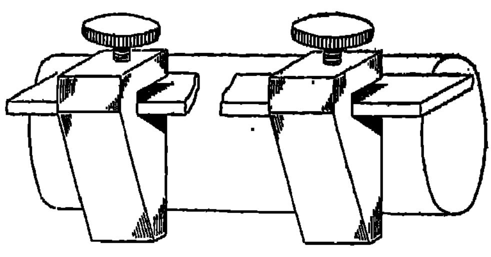

Fig. 3.—Key-seat Rule.

For making measurements more accurately than can be done with a graduated rule, a micrometer is employed which in principle may embody either a very fine screw thread of

suitable fractional pitch, or a vernier scale attached to a screw-operated frictional contact jaw.

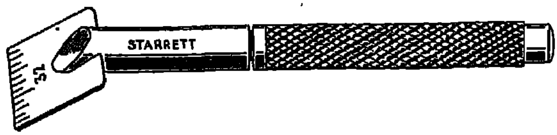

FIG. 4.—Short Rule.

Micrometers

The Screw Micrometer.—Fig. 5. depicts a typical high-grade one-inch micrometer mounted on a bench stand, and in Fig. 6 the constructional details of the instrument are shown. The movable jaw or spindle, which is provided with a screw thread of 40 threads per inch, is actuated by the knurled thimble whose position is indicated by the sleeve graduations, each of which

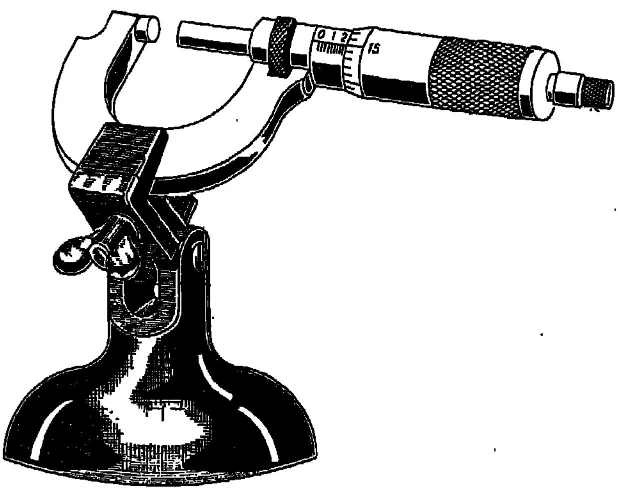

FIG. 5.—Screw Micrometer.

represents one turn of the thimble and 1/40 in.—or 25 thousandths of an inch—of axial movement. The bevelled edge of the thimble is in addition graduated in twenty-five divisions, each of which therefore represents an axial movement of the spindle of one-thousandth of an inch.

The micrometer illustrated has several detail refinements: the anvil is adjustable and can be locked in position by a clamping screw; a clamping ring for locking the spindle is provided;

an adjusting nut is fitted for taking up wear in the screw operating mechanism; a spring-loaded clutch with ratchet-stop is fitted to the spindle to ensure that uniform pressure is applied when using the instrument.

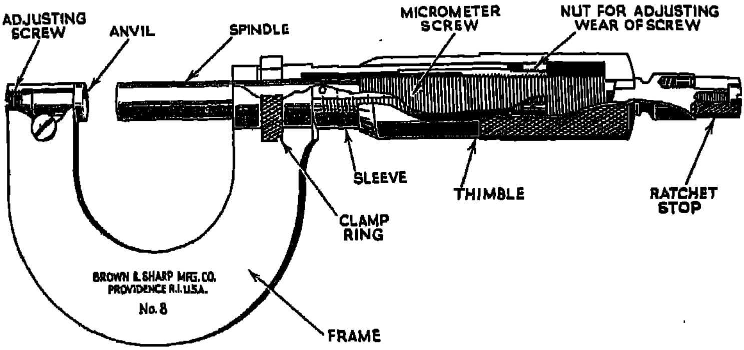

Fig. 6.—Screw Micrometer—Constructional Details.

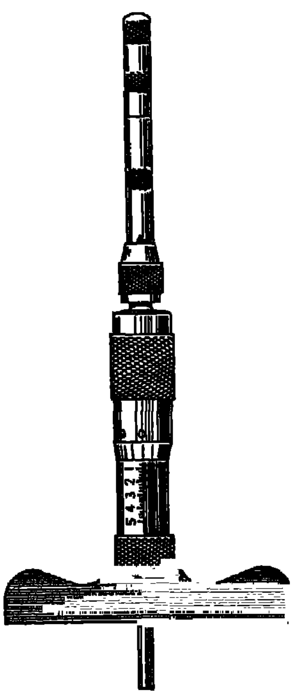

Fig. 7.
Micrometer Depth Gauge.

A standard setting gauge is supplied with micrometers of a range exceeding one inch to enable the zero position of the instrument to be adjusted if required.

If the accuracy of the micrometer is to be preserved, great care must be exercised when making measurements; the instrument should never be forced on to or off the work or used as a fixed gauge, rather should it be engaged and disengaged by means of the ratchet stop. Moreover, the micrometer should not be unnecessarily exposed to abrasive dust or allowed to lie on the bench, but after use should be returned to its stand and set aside in a safe place.

Micrometers are obtainable graduated with an additional vernier scale on the sleeve to enable readings of a ten-thousandth of an inch to be made.

For making internal measurements micrometers are provided with projecting jaws, reduced in size at their tips to allow them to enter a hole of less than ¼ in. diameter; the spindle thread is usually formed left-handed so that the jaws open when the thimble is turned in the usual forward direction.

Where the measurement of depth by the rule and slide device shown in Fig. 2 is not sufficiently accurate, a *Micrometer Depth Gauge* of the type shown in Fig. 7 may be used. In use, the foot-piece of the device is held firmly in contact with the surface of the work, and, when the spindle has been turned until it is felt to bottom, the reading is taken on the micrometer scale.

Extension pieces can be fitted to the spindle, if required, for measuring deep holes.

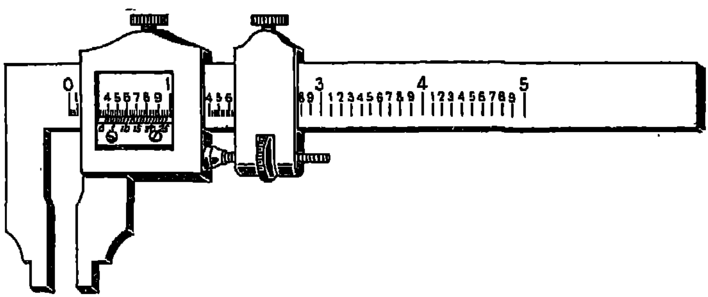

FIG. 8.—Vernier Micrometer.

The Vernier Micrometer. From the illustration in Fig. 8 it will be seen that the blade of the instrument carrying the fixed jaw is graduated in fractions of an inch, whilst the screw-operated sliding jaw is inscribed with a vernier scale. The blade is usually graduated in numbered inches and 1/10 in., and the latter are subdivided into divisions of 1/40 in.

Although different makes of these vernier instruments vary in the method of graduation used, the operating principle is similar and the ultimate reading is taken in thousandths of an inch on the vernier scale.

One advantage of this type of micrometer is that its range is limited only by the length of the graduated blade, whereas the range of the screw micrometer is usually only a single inch; a limitation which may necessitate the purchase of several micrometers or a micrometer set with standard distance rods.

A further advantage of the vernier micrometer is that the

tips of the jaws are reduced in width to a fixed dimension to enable the instrument to be used for making inside measurements.

For making accurate measurements of depth the *Vernier Depth Gauge* shown in Fig. 9 may be used, and here again the range of the instrument is limited only by the length of the graduated blade.

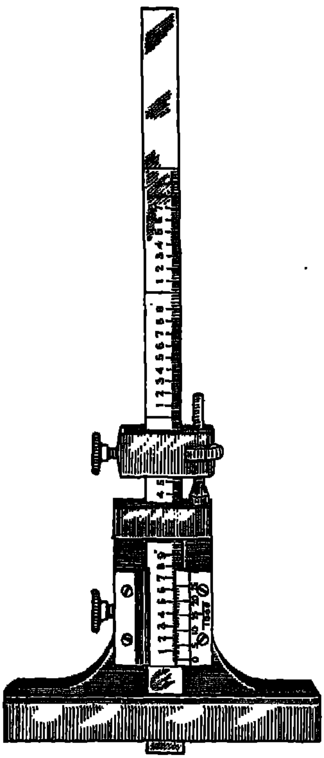

FIG. 9.
Vernier Depth Gauge.

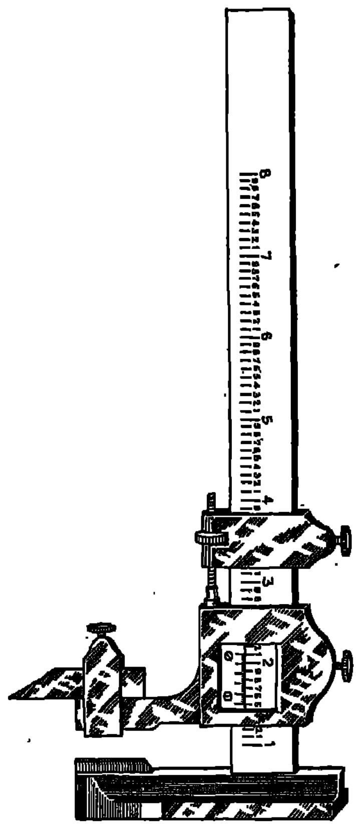

FIG. 10.
Height Gauge.

Similar in principle is the *Vernier Height Gauge*, illustrated in Fig. 10, which is used, in conjunction with an accurate surface plate, not only for measuring the height of components, but also for scribing lines at a given height from the base.

If desired, any of the micrometers or vernier instruments described can be obtained with metric instead of inch graduations.

The Dial Test Indicator

This precision instrument, which is illustrated in Fig. 11, is used chiefly for determining small variations of size or ranges of movement in thousands of an inch, but with the aid of standard gauges or distance rods it can be employed to measure absolute lengths.

As will be seen, the indicator is mounted on an adjustable arm, secured to a heavy base, for use on the surface plate, or on the bed or table of a machine.

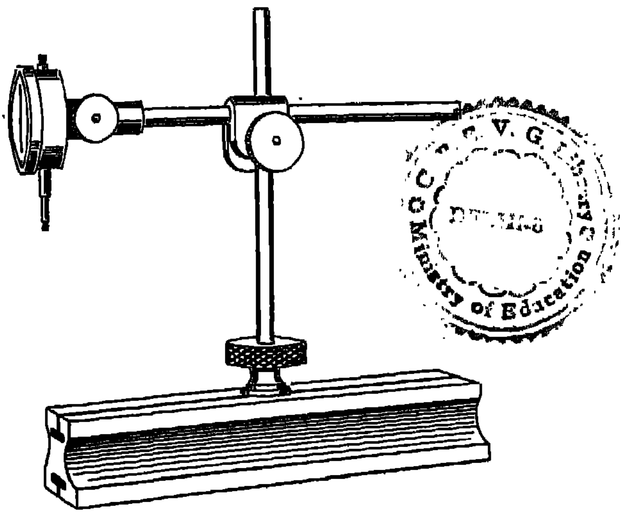

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FIG. 11.—Dial Test Indicator.

On the surface plate, variation of the height of components can thus be determined, and, when applied to parts rotating in a machine, the degree of eccentricity can be measured by the instrument.

The indicator can also be fitted to the slides of machine tools for accurately registering the amount of feed applied to the cutting tool.

The Starrett dial test indicator head can be attached to any surface gauge having a column of $\frac{5}{16}$ in. diameter, and when so mounted it is ideal for use in conjunction with the surface plate or on the lathe bed or machine table.

Squares

Squares are used not only for marking-out work but also for testing the accuracy and squareness of parts during production.

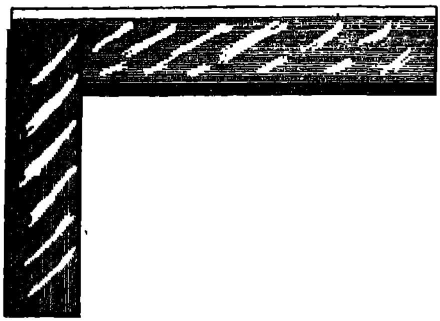

FIG. 12.
Square with Hardened Blade.

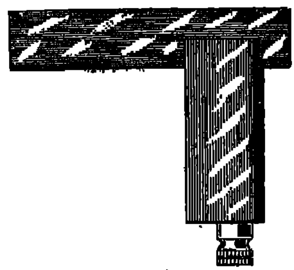

FIG. 13.
Toolmaker's Square.

The square shown in Fig. 12 is a high-quality tool fitted with a hardened blade, and the bevelled edges provided greatly facilitate the accurate checking of work.

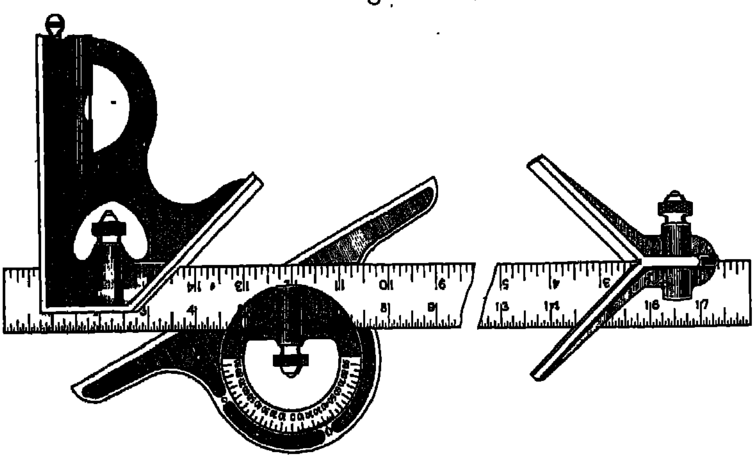

FIG. 14.—Combination Square.

The *Toolmaker's Square* depicted in Fig, 13 has an adjustable blade which enhances its adaptability for fine and intricate work.

If desired, squares of the usual types can be obtained with a graduated blade.

Fig. 14 illustrates what is termed a *Combination Square*, that is to say several fittings are adapted to clamp on to a grooved standard rule of twelve inches in length. On the left, the device forms the stock of an adjustable square which also carries a blade formed at an angle of 45 degrees, and in addition the stock is equipped with a spirit level and a removable scriber. The central component comprises an adjustable protractor-head graduated in degrees and furnished with a spirit level and locking screw. The device on the right has its jaws ground to a right angle, and when clamped to the blade it is used as a gauge for scribing centre lines on round material.

The Protractor

That shown in Fig. 15 is of simple construction and consists of a movable blade with clamping bolt registering with a rectangular stock which is graduated in degrees.

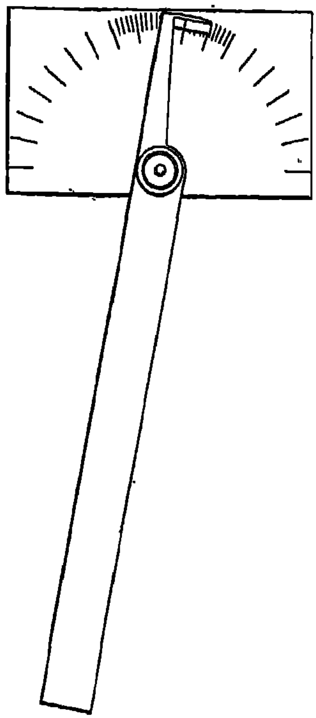

FIG. 15.—Protractor.

Callipers

Callipers, as opposed to micrometers, are generally used only for the rough estimation of size, and for this purpose the legs and points are adapted to suit special requirements.

Fig. 16 shows a light form of *Toolmaker's Calliper* fitted with a solid-nut screw adjustment, but the heavier patterns can be obtained with a split-nut for quick adjustment.

Callipers made for measuring the diameter over the crests of screw threads have the tips of their limbs flattened, and for measuring the root diameter of the thread the points are formed to a chisel-edge.

Again, for making inside measurements the tips are turned outwards, whilst for measuring the root diameter of internal screw threads the tips are in addition sharply pointed.

Both limbs are formed to a sharp point in the case of *Dividers*, which are used for measuring or setting-out the distance between two points as well as for scribing circles.

A special form, known as the jenny, odd-legs or *Hermaphrodite Calliper*, is shown in Fig. 17. This tool with its

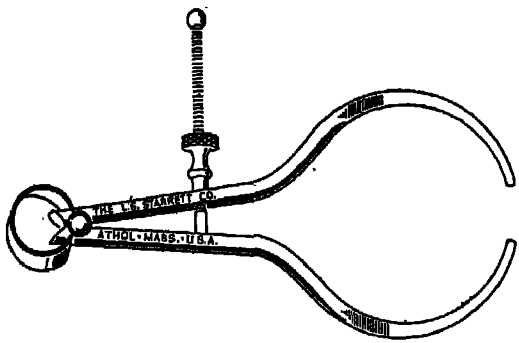

FIG. 16.—Toolmaker's Calliper.

curved guide-leg and sharp pointed scriber-leg is employed for scribing lines at a predetermined distance from a reference edge.

The screw-adjustable type of jenny calliper illustrated is set for use by placing the tip of the guide-leg in contact with the end face of a rule, and then turning the adjusting nut until the scriber point registers with the graduation required.

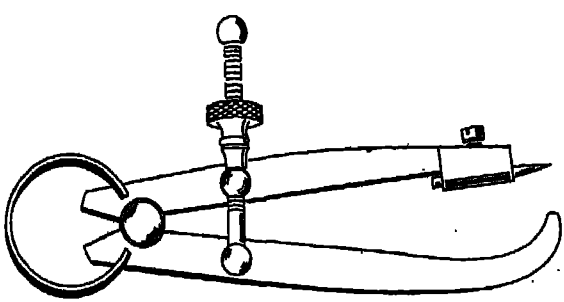

FIG. 17.—Hermaphrodite Calliper.

Some mechanics, however, prefer a simpler form of this calliper with a plain friction joint, and in this case the tool is set by engaging the point with the rule graduation required, and then pressing the guide leg into contact with the end of the rule.

Fig. 18 illustrates a *Micrometer Calliper* which has a wide range of application in the workshop. This device is fitted with a short pivoted leg, operating a pointer over a range of four thousandths of an inch on either side of the central zero marked on the scale.

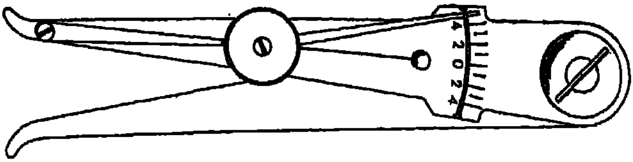

FIG. 18.—Micrometer Calliper.

In the absence of an internal micrometer, an internal measurement can be made by transferring a reading of the calliper to an outside micrometer, and in this way the accurate fitting of bushes to shafts can be readily carried out, or interference fits can be measured and the parts machined accordingly.

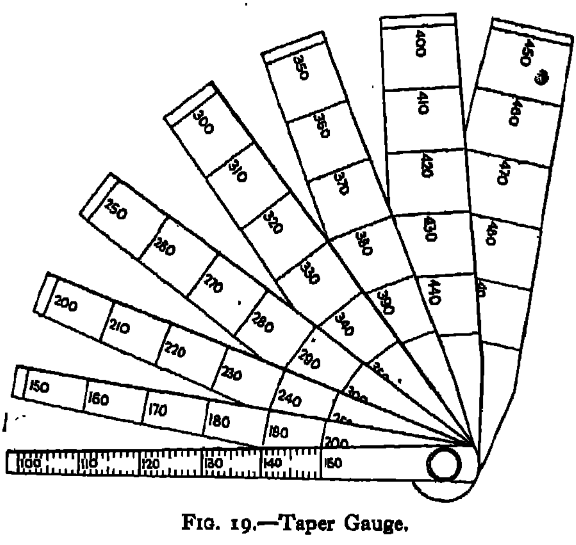

FIG. 19.—Taper Gauge.

Moreover, the parallelism of a bored hole, up to a depth of four inches, can be accurately checked by careful manipulation of the calliper, and, in addition, the instrument can if desired be converted into an outside micrometer calliper by merely rotating the legs.

Gauges

There are many forms of gauges in common use for either the direct or indirect measurement of dimensions.

The Taper Gauge illustrated in Fig. 19 is graduated in thousandths of an inch over a range of from $\frac{1}{16}$ in. to $\frac{1}{2}$ in., and a similar gauge of larger size is also made reading from $\frac{1}{2}$ in. to 1 inch.

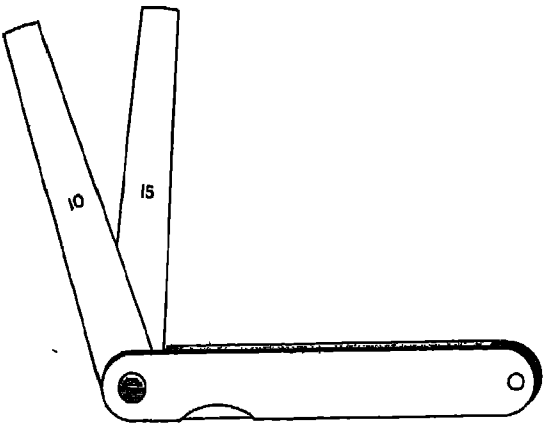

FIG. 20.—Feeler Gauge.

This gauge is used for determining the internal diameter of tubes and bored holes, and thus may to some extent replace the internal micrometer, but it will be appreciated that it may not always be possible to measure the bore of a shallow hole in this way.

Although direct reading gauges of this type are made, graduated from 0·010 to 0·150 in., for determining the width

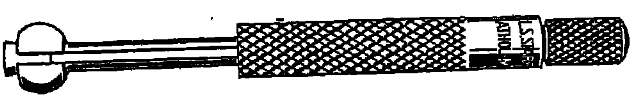

FIG. 21.—Expanding Gauge.

of narrow slots or gaps between components, more often a feeler gauge is used for this purpose.

A small *Feeler Gauge* is shown in Fig. 20; here, the blades, which are numbered in thousandths of an inch, can be used singly or in combination when measuring clearances.

For measuring the internal diameter of bored holes the *Expanding Gauge*, shown in Fig. 21, may be used in conjunction

with an external micrometer instead of taking a direct reading with an internal micrometer.

This instrument has two hemi-spherical contact pieces of hardened steel which are normally held in contact by their spring mountings. After insertion of the device in the hole, these contact members are expanded by the action of the tapered plug and screwed finger-nut until contact is established; the diameter of the gauge head is then measured with an external micrometer.

Other forms of adjustable internal gauges are made with spring-loaded telescopic contact pieces, but these may be found rather more difficult to operate accurately.

The familiar *Drill Gauge* is illustrated in Fig. 22, and here the fractional inch pattern with decimal equivalents is shown, but these gauges can also be obtained for wire-size drills from No. 0 to No. 60 and from No. 61 to No. 80.

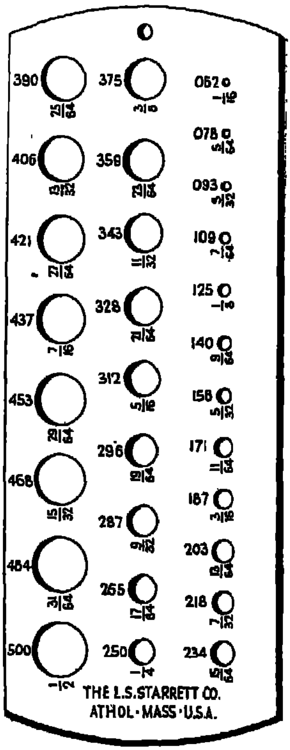

FIG. 22.—Drill Gauge.

In addition, gauges are made in this form to indicate the size of tapping drills as well as the fractional inch and B.A. screw diameters.

The Radius Gauge illustrated in Fig. 23 is fitted with a series of blades, each of which is formed to both a convex and a concave profile of specified radius. This tool will be found especially useful for shaping form-tools employed for machining curved surfaces.

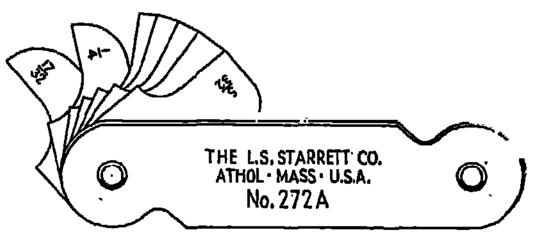

FIG. 23.—The Radius Gauge.

For estimating the pitch of either inch or metric screw threads, the pattern of *Screw Pitch Gauge* illustrated in Fig. 24 is most convenient.

When setting a screw-cutting tool in the lathe, the use of the *Tool Setting Gauge*, illustrated in Fig. 25, will enable the

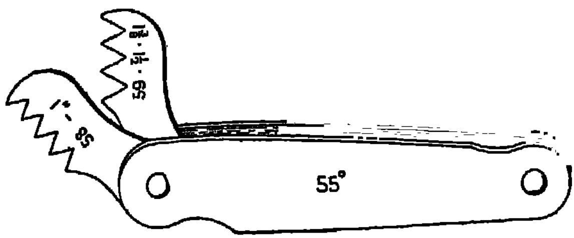

FIG. 24.—Screw Pitch Gauge.

tool to be adjusted with its cutting edges at the correct angle to the work. One edge of the gauge is applied to the work or to the face of the chuck, and the tool point is brought into accurate alignment with the sides of the V opening.

Another useful form of gauge is the lathe *Tool Height Setting Gauge* as depicted in Fig. 26. A gauge of this type may be of a variety of forms for use on either the cross-slide or the bed of the lathe.

Under manufacturing conditions where components are

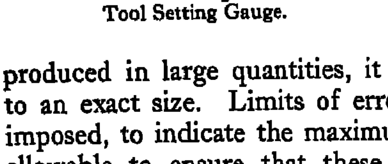

FIG. 25.
Tool Setting Gauge.

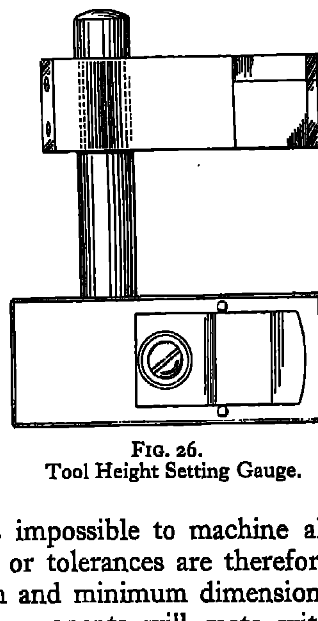

FIG. 26.
Tool Height Setting Gauge.

produced in large quantities, it is impossible to machine all to an exact size. Limits of error or tolerances are therefore imposed, to indicate the maximum and minimum dimensions allowable to ensure that these components will mate with other parts during assembly.

To facilitate inspection and to ensure the rejection of over- and under-size parts, the internal diameter of the bore of components may be checked by a *Limit Gauge* of the type shown in Fig. 27. The smaller but longer cylindrical end of the gauge should pass through the part, but the shorter and larger end must not enter.

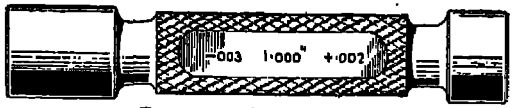

FIG. 27.—Limit Gauge.

As the gauge is made to size in accordance with the allowable tolerances, it will readily determine any departure from the standard imposed.

In the same manner, checking of external dimensions can be carried out with a gauge of the form shown in Fig. 28.

If on the other hand, an adjustable limit gauge as illustrated in Fig. 29 is used, the prescribed tolerances can be set as required for any particular batch of components.

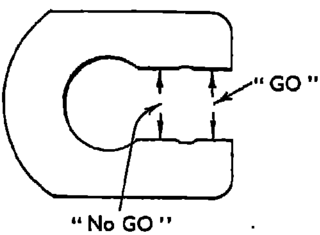

FIG. 28.—Gauge.

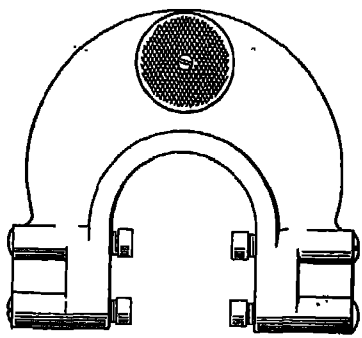

FIG. 29.—Adjustable Limit Gauge.

The Surface Plate and Accessories

For marking-out work, a machine-finished surface plate or marking-out table will usually be found sufficiently accurate, but where the plate is used as a standard for finishing flat surfaces by scraping, a hand-scraped surface plate is necessary.

A small ground and lapped surface plate is made by Messrs. Moore & Wright for the use of toolmakers, and for other work where a very high degree of accuracy is required.

A sheet of plate glass can also be used as a surface plate when the more usual form is not available.

Fig. 30 depicts a surface plate fitted with lifting handles, but this feature survives in part from the time when the surface

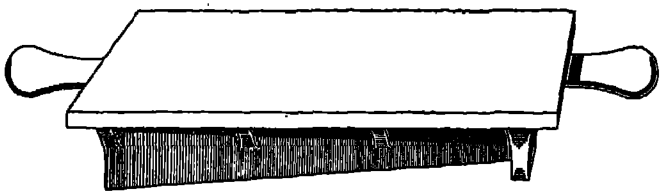

FIG. 30.—Surface Plate.

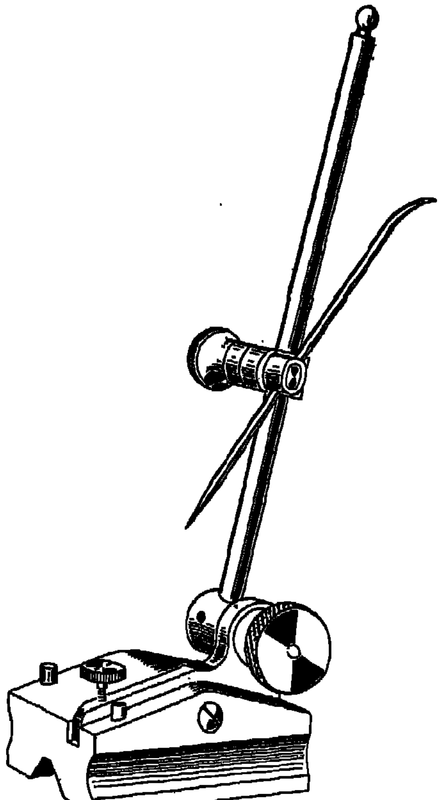

FIG. 31.—Surface Gauge.

plate was used in the inverted position when scraping the valve faces of steam engines.

The bed of the plate is of heavily ribbed box construction, and in the case of the more massive surface plates, the lifting handles facilitate changes of position.

When the surface plate is used for the purpose of marking-out components, some standard accessories are required to assist in the work and to ensure accuracy.

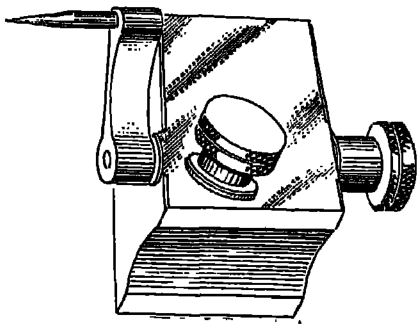

FIG. 32 (A).—Dwarf Surface Gauge.

The Surface Gauge shown in Fig. 31 has a ground flat base carrying a pivoted scriber arm, which is moved by a fine screw adjustment to set the scriber point, so that lines can be inscribed on the work at a predetermined distance from the surface of the table.

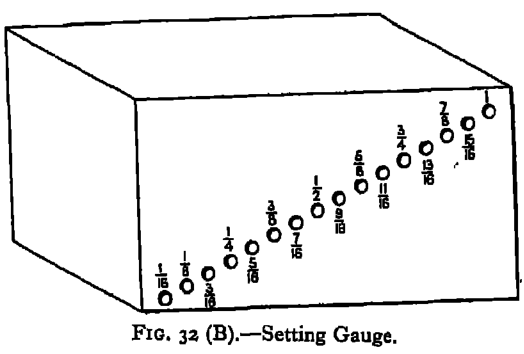

FIG. 32 (B).—Setting Gauge.

Moreover, the base of the gauge is provided with two retractable guide pegs, which enable lines to be scribed parallel with the edges of the surface plate.

For small work and for scribing lines up to a distance of an inch from the surface of the table, the dwarf surface gauge shown in Fig. 32A will be found convenient. Here, the scriber

after it has been adjusted by means of the knurled finger nut, is locked in position by turning the knurled clamping screw seen on the upper surface of the base.

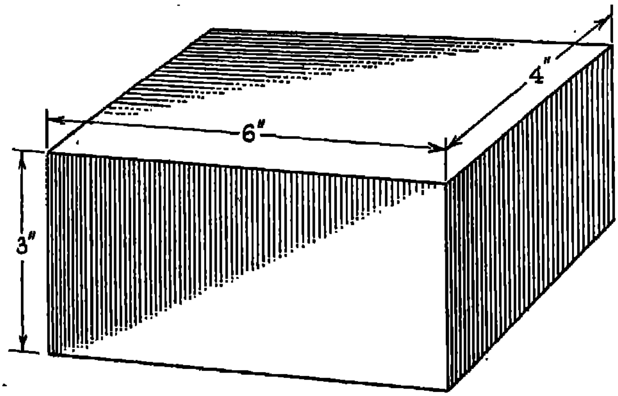

FIG. 33.—Surface-Ground Block.

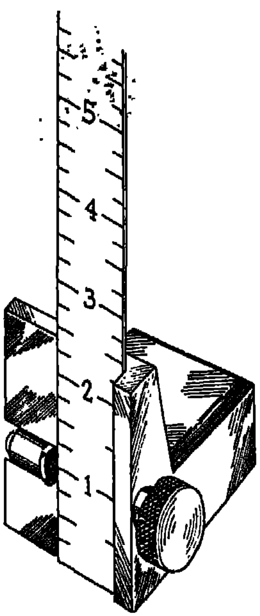

FIG. 34.—Rule Holder.

When adjusting this tool, a special setting gauge as shown in Fig. 32B may be used in conjunction with the surface plate.

This gauge is drilled by means of a fine drill with a series of holes ranging from $\frac{1}{16}$ in. to 1 in. from the base, and, if desired, a further set of holes registering thirty-seconds of an inch can be drilled on the other face of the block.

When marking-out flat material it is essential for the sake of accuracy that it should be maintained in a truly vertical position, and to facilitate this as well as many other operations carried out on the surface plate, the *Surface-Ground Block* depicted in Fig. 33 may be used with advantage.

Furthermore, when adjusting the height of the scriber point of the surface gauge it is important for accurate setting that the rule should be held vertically, and to ensure this the *Rule Holder* illustrated in Figs. 34 and 35 was designed. In addition to

holding the rule securely and accurately, this device has the advantage of accommodating any rule of standard width.

Reference to Fig. 26 will show that the tool setting gauge, there illustrated, is also made to serve as a vertical rule holder

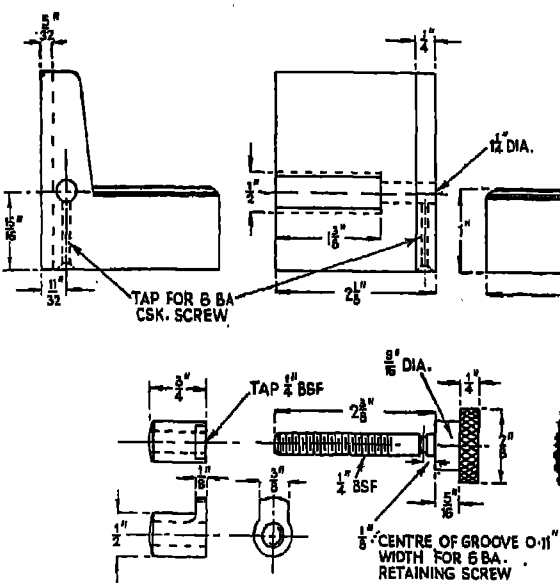

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Fig. 35.—Rule Holder.

by the provision of a spring clip and two register pegs against which the rule abuts.

When positioning work to be marked-out on the surface

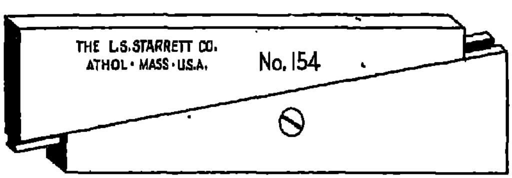


Fig. 36.—Adjustable Parallels.

plate, it may be set at a known height by employing the special *Ground Strips* made for this purpose, or, again, the height may be accurately adjusted by means of the *Adjustable Parallels* illustrated in Fig. 36.

Clamps

For holding cylindrical material during marking-out, the use of *V Blocks and Clamp*, as shown in Fig. 37, will ensure that the work is held securely and in parallel alignment with the surface of the table.

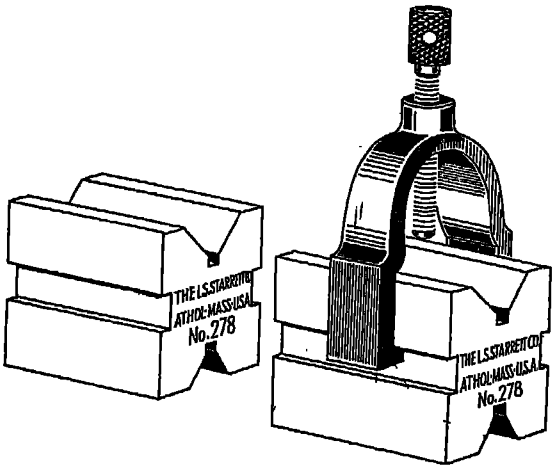


FIG. 37.—V Blocks and Clamps.

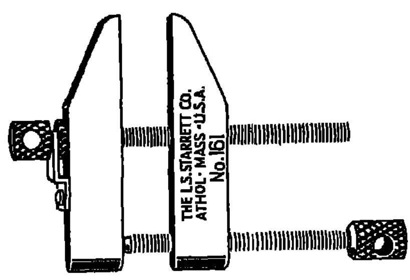


FIG. 38.—Toolmaker's Clamp.

For holding flat material or for securing two parts together for marking-out or machining, the *Toolmaker's Clamp*, illustrated in Fig. 38, affords a firm hold without causing damage to the work.

The Scriber

When marking-out by hand the *Scriber* is employed, and the pattern shown in Fig. 39 will be found especially serviceable

as it has a collet-held detachable point and a top of hexagon form to prevent it from rolling off the bench and suffering damage to the point.

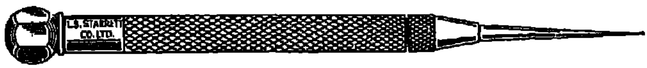


FIG. 39.—The Scriber.

Punches

After marking-out it is usual to dot-in the reference lines and the centres of circles. This should be done with a fine *Centre Punch* of the type shown in Fig. 40, or an automatic centre punch may be used.

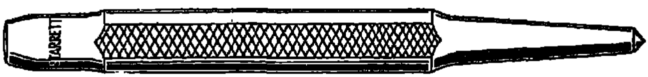


FIG. 40.—Centre Punch.

The Automatic Centre Punch, illustrated in Fig. 41, has the advantage of delivering uniform blows of adjustable force, and as only one hand is required for this operation the other can be used to steady the work.

From the details given in the drawing it will be seen that the force of the blow struck is regulated by turning the knurled cap and thus compressing the operating spring.

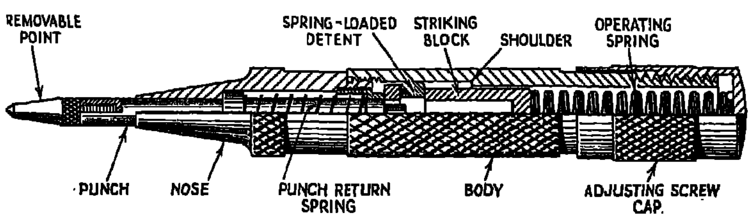


FIG. 41.—Automatic Centre Punch.

The punch point is readily replaceable and its fineness facilitates accurate marking-out.

With regard to the mechanism of the punch; the striking block is provided with a detent which is normally held outwards by a flat spring against the punch body.

When downward pressure is applied, the punch member moves upwards and a shoulder on its upper end engages the detent, carrying it upwards together with the striking block. Continuation of this movement causes the detent to be pressed inwards by a shoulder formed within the punch body, thus releasing the striking block which, under the influence of the operating spring, strikes a blow on the part carrying the punch point. When the hand pressure is released, the return spring resets the mechanism ready for further operation.

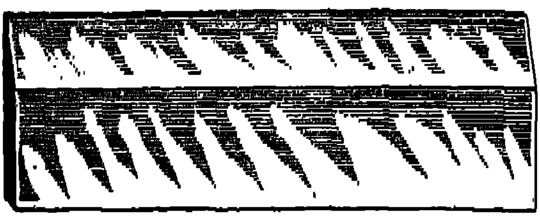


FIG. 42.—Straight Edge.

The Straight Edge

This is shown in Fig. 42 and it can be obtained in lengths ranging from a few inches to several feet.

It is used for ascertaining the flatness of surfaces and the straightness of filed or machined work; in addition, it can be employed in conjunction with a setting block for adjusting work on the surface plate or machine table.

CHAPTER III

SCREWING TACKLE, DRILLS AND REAMERS

Screw Threads. Screwing Tackle. Lathe Tailstock Die-Holder. Taps. Tap Wrenches. Tapping Operations. Drills. Countersinks and Spot-Face Cutters. The Hole Cutter. End Mills. Reamers. Hand Reamers. Machine Reamers. Morse Taper Reamers. Taper-Pin Reamers.

Screw Threads

AMONGST the great variety of operations the metal-working shop is called upon to perform, one of the greatest importance is the cutting of screw threads.

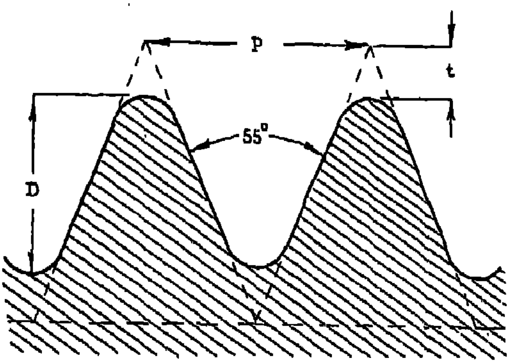


FIG. 1.

P = Pitch and is equal to $\frac{1}{\text{No. of threads per in.}}$

t = Depth of rounding-off at top and of filling-in at bottom of thread } = ·16 P.

D = Actual Depth = ·64 P.

This may be accomplished either by a machining process in the lathe, by milling in special machines designed for the purpose, or, more usually, by cutting the threads with special tools for use by hand on the bench, or in conjunction with the lathe or drilling machine.

Screw threads vary in form in accordance with the use to which they are put, and also according to the country from which they originate.

In this country the Whitworth V—Standard thread is used for almost all engineering work. This thread is of triangular form with an included angle of 55 degrees between the sides, whilst the crown and root are rounded as depicted in Fig. 1, where the general proportions of the thread are shown.

As will be evident, the pitch of any thread is the distance between two adjacent crowns.

The Whitworth form is quite satisfactory for use in the larger sizes, but, owing to the coarseness of the pitch relative to the diameter, small bolts and screws are unduly weakened by reason of their relatively small core diameter.

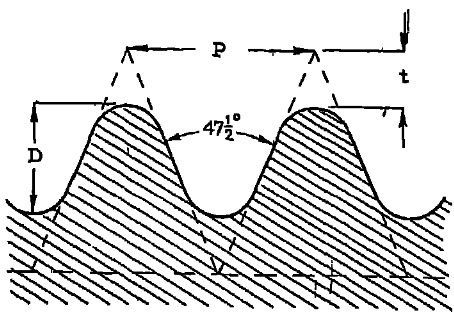


FIG. 2.

P = Pitch and is equal to $\dfrac{1}{\text{No. of threads per millimetre.}}$

t = Depth of rounding-off at top and of filling-in at bottom of thread . . } = ·268 P.

D = Actual Depth = ·6 P.

In view of this, and because of its superiority when employed with screws subject to shock or vibration, a British Standard Fine thread has been devised and widely adopted in general engineering practice. This thread has a much finer pitch than the Whitworth Standard but the Whitworth V form is retained.

For instrument work and small electrical fittings the British Association standard thread has been generally adopted in this country. Here, the thread angle is $47\frac{1}{2}$ degrees, and the proportions are as shown in Fig. 2. The maximum diameter of this standard is 0·236 in. and the minimum in general use 0·031 in., represented by No. 0 B.A. and No. 16 B.A. respectively.

In addition to the British Standard Fine thread mentioned above, there are various other classifications using the Whitworth V thread of 55 degrees angle; these are the British Standard Pipe thread of varying pitches according to size: the Standard Brass thread with a pitch of 26 threads per inch throughout the scale; and the original Model Fittings thread with a pitch of 40 threads per inch up to ¼ in. diameter, and increasing to 26 threads per inch for ½ in. diameter.

In addition, to meet special trade requirements, taps and dies of 40 threads per inch are now manufactured up to ½ in. diameter, as well as screwing tackle of 60 threads per inch in the smaller sizes.

A further addition to the V thread form should be noted, namely the thread standardized by the Cycle Engineers Institute which has an included angle of 60 degrees.

Failure to realize this point may cause difficulty when endeavouring to fit nuts of Standard Whitworth form to components threaded with cycle standard dies, or again, as some of the larger cycle sizes are threaded 26 threads per inch, confusion with the Standard Brass thread may arise.

There are, of course, other forms of screw threads which are not usually cut with hand tackle, as, owing to their special form, they are more readily produced by a screw-cutting operation in the lathe.

Owners of machinery manufactured abroad will be aware that the screw threads employed differ from those commonly used in this country. On the Continent the International Metric thread is in general use, and in this case both the pitch and the diameter are expressed in accordance with the metric system. In the U.S.A. a thread of similar form is used, but the pitch and diameter are standardized relative to the inch.

As a useful reference book for information with regard to screw threads of various forms and drill sizes, the Model Engineer publication entitled *A Guide to Standard Screw Threads and Twist Drills* is recommended; this is published by Messrs. Percival Marshall & Co. Ltd.

Screwing Tackle

To cut screw threads by hand, a die is required to form the male thread and a corresponding tap to cut the female counterpart, whilst, in addition, a die-stock to hold the dies and a tap wrench to turn the taps are necessary.

With modern taps and dies it is usually possible to form the thread at a single pass, at any rate in the smaller sizes, although for coarse pitches in sizes larger than half-inch some manufacturers make provision for a fairly wide range of adjustment.

Formerly, the type of die-holder used was that shown in Fig. 3, but considerable skill was required in using this tool to avoid tearing the thread when nearing completion.

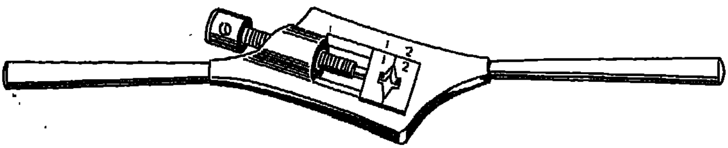


FIG. 3.

As will be seen, the die-holder is provided with a pair of V-guides into which the half dies are inserted, and the dies are then closed on to the work by the action of the adjusting screw pressing against the upper die.

The action of this tool was often to rub away the metal rather than to cut it, and any attempt to hasten the process frequently resulted in partial removal of the thread already formed. Such apparatus, although still to be found, is more useful for dressing damaged screw threads than for the purpose for which it was originally intended.

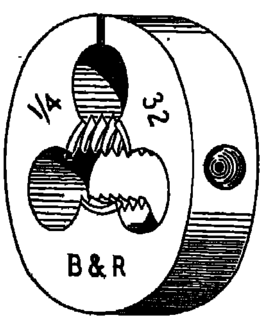


FIG. 4.

With the acceleration of modern industrial engineering processes, it was inevitable that the operation of screw-threading should receive the attention that resulted in the development of the present circular die and its variants. As will be seen in Fig. 4, the die consists of a disc of hardened tool-steel in which the required thread has been cut. In order to form the cutting edges and to provide escape for the chips formed when working, three or more holes are drilled to break into the threaded centre of the die, and the thread is relieved on that face of the die normally presented to the work.

The die is sharpened by honing the edges of the thread where they project into the drilled clearance holes.

These dies are often split and are, in addition, provided with a setting screw to afford a fine adjustment for the accurate sizing of the thread cut.

Latterly, however, a solid form of circular die has been introduced into this country following their inception by Messrs. Johanssen of Sweden, and excellent examples are now manufactured here. Fig. 5 illustrates a die of this type.

These solid dies, when used in conjunction with taps made by the same manufacturer, cut accurate threads of exactly the correct mating size.

It is opportune here to stress the importance of buying best quality taps and dies, for the leading makers, by painstaking research, manufacture, and inspection, take the greatest

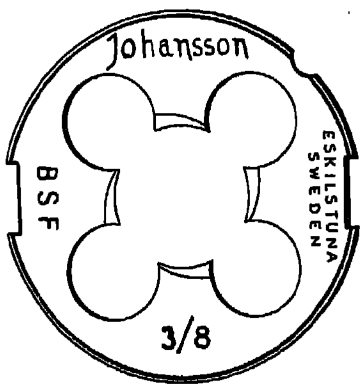


FIG. 5.

care to ensure that their products are accurate in all respects, and will cut threads in accordance with a recognized standard.

Although it follows that such products are relatively expensive, their accuracy and efficiency are beyond doubt.

The cheaper qualities of screwing tackle, on the other hand, often fail to cut threads of correct pitch or diameter, with the result that these threads will not mate accurately with those produced by the taps and dies of the same or of another manufacturer.

As an example of dies having a moderate range of adjustment, those made by Messrs. The Wells Bros. Co. of America may be cited. Fundamentally, these dies are similar to those used in the die-stock shown in Fig. 3, but they have greatly improved cutting powers and can be relied upon to cut accurate threads.

Fig. 6 shows a cut-away section of this form of die which is marketed under the title Little Giant.

It will be seen that the two cutting members are housed in a cylindrical steel cap, which has a transversly machined slot with a bevelled contact surface to afford guidance for the dies.

As will be seen in the drawing, adjustment for depth of cut is provided by set-screws which bear on the cutting members, and the complete assembly is held in place by a threaded guide collet which ensures that the dies are at all times positioned square to the work.

This screw-cutting gear is made in sizes ranging from $\frac{7}{64}$ in. to $1\frac{1}{2}$ in., and the complete range is covered by six sets of tackle.

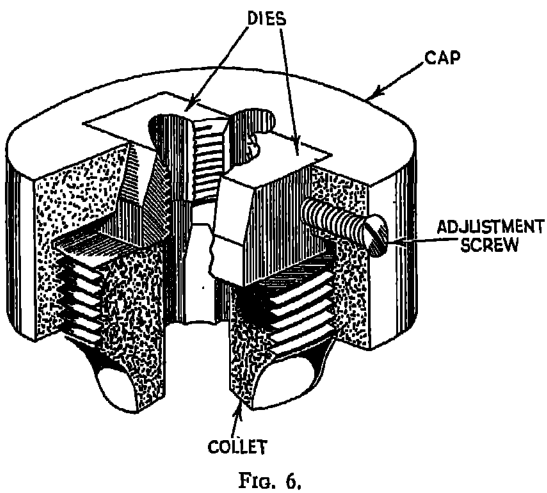


FIG. 6.

For accurate screw-threading by hand, it is essential that the die or die-holder should be provided with some form of guide collet to maintain the die truly at right angles to the work. Messrs. Pratt & Witney, and also S. W. Card of America, manufacture die-holders provided with housings to accommodate standard circular dies in conjunction with removable collets, which latter, unlike the Little Giant type, are quite independent of the die itself.

This form of construction has the advantage of facilitating the cutting of a thread on the reduced portion of the end of a shaft of greater diameter; for example, an $\frac{1}{8}$ in. diameter spigot at the end of a $\frac{1}{4}$ in. shaft may be threaded by securing an $\frac{1}{8}$ in.

die in the upper housing of the die-holder and a ¼ in. collet in the lower.

Fig. 7 shows the details of the Card die-holder and the collets used with it.

Messrs. Pratt & Witney also manufacture sets in which the body of the die is made to serve as a collet, but in this case, if it is desired to carry out the operation outlined above, it will be necessary to change the die from one body to another having the correct size of collet.

This arrangement suffers from the possible disadvantage that the collet may not project sufficiently to engage the larger shaft diameter, whereas with the removable collet design

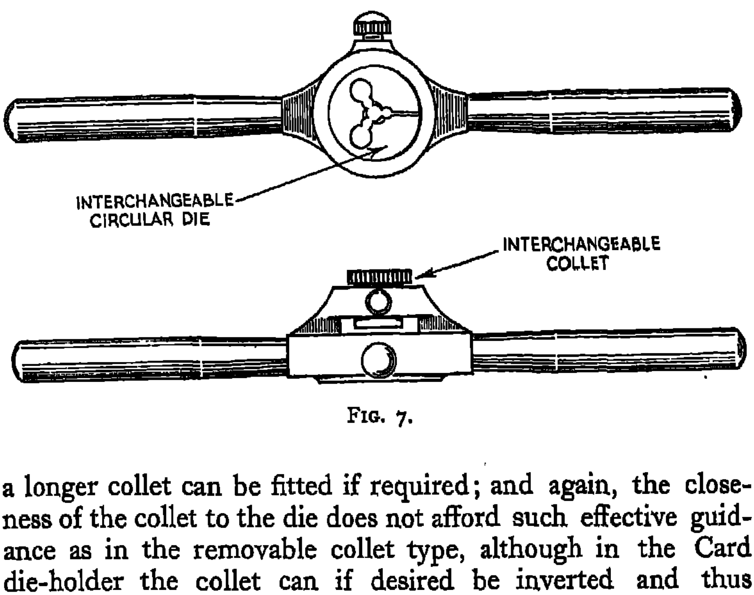


FIG. 7.

a longer collet can be fitted if required; and again, the closeness of the collet to the die does not afford such effective guidance as in the removable collet type, although in the Card die-holder the collet can if desired be inverted and thus positioned close to the die.

Lathe Tailstock Die-Holder

It is often required to thread quickly and accurately small components such as bolts and screws which are being machined in the lathe.

This can be readily accomplished by mounting in the lathe tailstock a special die-holder of the type shown in Fig. 8.

This device holds standard circular dies and is provided with a tapered spigot to fit the tailstock spindle; this spigot

has a parallel portion along which the die-holder itself is free to travel.

Resistance to the cut is taken through the ball-ended handle, which is either held by the operator or engaged with the lathe top-slide or other convenient support.

To operate the die-holder it is engaged with the work by means of the tailstock screw, or by hand in the case of small threads, while the lathe mandrel is slowly revolved.

As soon as the die begins to cut, the holder will be drawn along the work and no further pressure need be applied.

When a sufficient length of thread has been formed, the lathe is reversed and the die-holder will travel backwards clear of the work; nevertheless, care must be taken to ensure that

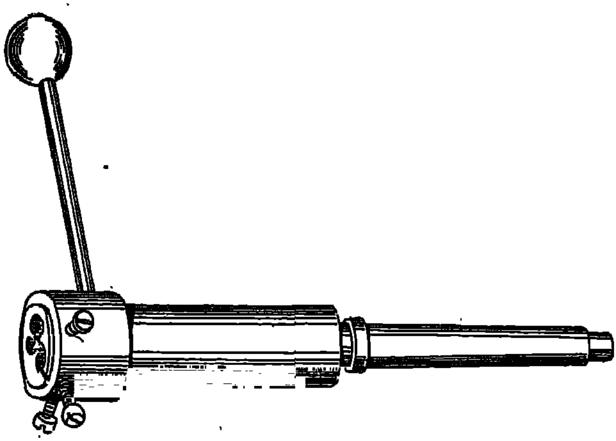


FIG. 8.

the tailstock is withdrawn sufficiently to allow of this, otherwise the threads will be damaged.

If the lathe is revolved under its own power, great care must be taken to guard against damage to the work by jambing or over-running, and also to avoid injury to the hands in the confined working space available.

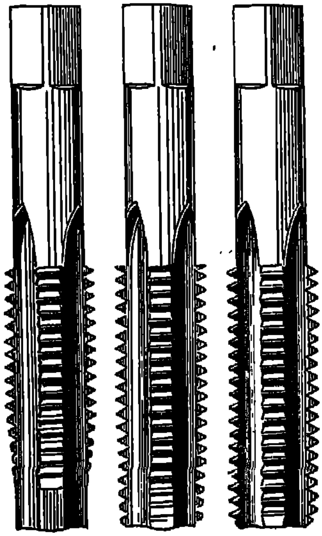
For cutting short threads on small components it is safer to turn the mandrel by means of a handle specially made for the purpose, for this not only allows of instant stoppage and reversal but also acts as a sensitive feed, which is especially useful in the case of fine work.

In spite of what has been said, it should, perhaps, be pointed out that when coarse threads are being cut in this way, the

resistance to the forward travel of the die may cause thinning of the initial threads, and to counteract this adequate tailstock pressure should be maintained until the die is well engaged with the work.

Taps

Taps are of two main types, namely, hand taps and machine taps. The former, as their name implies, are for use at the bench by hand, and the latter in a variety of forms are employed in machines designed for tapping work ranging from small nuts to large castings.



TAPER SECOND PLUG

FIG. 9.

In the case of the hand variety, these are usually made in sets of three taps, named, Taper, Second and Plug.

The first is used to start the tapping operation: the second to follow the first when the hole is deeply threaded: and the third is employed to form a thread to the bottom of a drilled hole. Fig. 9 depicts these three forms, and it will be seen that the first is tapered throughout its length, whilst the second has only a short lead confined to the first few threads. The plug tap has little or no lead, and in the case of the larger sizes made by some manufacturers, is the only one of the three with full diameter threads.

It is usual to make the shanks of large taps smaller than the core diameter, but this does not apply to those smaller than ¼ in. to avoid unduly weakening the shank.

The shanks of machine taps, except in the smallest sizes, are usually made of lesser diameter than the core size to enable a quantity of nuts to pass on to the shank, and thus avoid the necessity of reversing the machine to clear single nuts from the tap.

Fig. 10 shows the type of machine tap used for threading nuts, and as will be seen, its overall length is nearly twice that of a hand tap, and it has a plain cylindrical shank with no provision for attaching a tap wrench.

Where a high degree of accuracy in tapping operations is required, manufacturers recommend ground-thread taps, which are much superior to the common tap as they are ground in the angle, on the outside, and in the root of the thread.

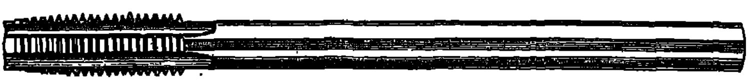


FIG. 10

In addition, the shank is ground truly concentric with the threaded portion to ensure true running in the tapping machine.

Any tap may be used successfully in a machine, provided that it runs truly, but any eccentricity will tend to form an over-size thread and may result in the breakage of the tap.

Apart from the greater accuracy obtained by the use of ground-thread taps, freer cutting is ensured and a high finish is imparted to the work.

Tap Wrenches

Formerly, the tap wrench consisted of a bar flattened at its centre and provided with a series of square holes to accommodate taps of various sizes. These wrenches were ill-suited for their purpose as they were too large for the smaller taps and the arms afforded unequal leverage.

Nowadays, many excellent types of tap wrenches are readily obtainable, and some of the more widely-used forms are illustrated in Fig. 11.

Tapping Operations

Where a special tapping attachment is not available, quite satisfactory work can be carried out in the drilling machine with the tap held in the drill chuck.

When a number of small nut blanks has to be threaded in this way, they are held in a special fixture on the drilling table.

This device is provided with a clearance way for the tap and locates the blanks without allowing them to rotate, but at the same time it leaves them free to rise on completion of the tapping operation.

If the diameter of the shank is less than the thread core diameter, the tap can be fed downwards until the blanks after clearing the thread come to rest on its shank.

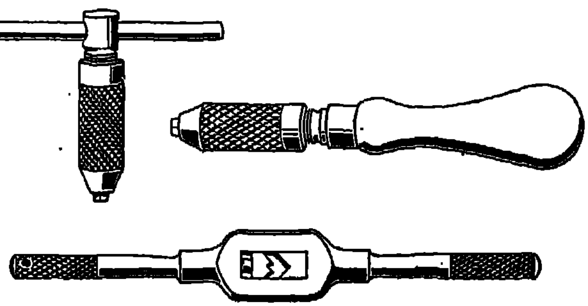


FIG. 11.

In this way, it will only be necessary to stop the drilling machine to clear the accumulated nuts from the shank after removing the tap from the chuck.

When tapping larger work, the drill spindle may be rotated by hand by means of a handle attached to its upper end, so that the tap can be turned to and fro and withdrawn when required.

In the event of the work being held by one hand on the drill table and the spindle rotated with the other, the tap may be engaged by foot operation of a cord attached to the feed lever of the machine.

Work machined on the lathe mandrel may be threaded by means of a tap held in the tailstock drill chuck.

In this case, the chuck is tightened sufficiently to afford guidance for the tap but not to prevent its rotation, for the

latter is controlled by means of a tap wrench which is either held in the hand or is engaged with the lathe top-slide.

In all tapping operations the drilled hole should be of a size to allow free-cutting of the tap, and it should be borne in mind that the action of the tap to some extent sets up the crests of the thread, and so compensates for some excess over the theoretical tapping size of the hole.

To save unnecessary labour, a series of trial holes of various sizes should be tapped to determine the largest permissible to allow a full or nearly full thread to be cut.

When using the larger sizes of taps in the drilling machine or lathe, some difficulty may be experienced in completing the tapping operation, but if the tap is first given a sufficient bearing in the hole, the work may be finished by hand on the bench without fear of inaccuracy.

It is essential when tapping by hand to maintain the tap truly at right angles to the work, and this is facilitated if the tap is free-cutting and has not to be forced into an unduly tight hole.

If the tap is started correctly and is turned with care, it will tend to cut truly and to follow the line of the drilled hole, but, as a precaution, a check should be made from time to time with a small square engaging the tap in two planes at right angles.

When a parallel hole is tapped, it will be found that the surface of the work immediately round the hole is raised; to obviate this and so to ensure the accurate fitting together of parts, the hole should be enlarged to the clearing size to a depth of one full thread prior to tapping.

To promote free-cutting and a good finish on the work, the tap should be kept well-lubricated when in operation. For this purpose, lard oil is perhaps the best lubricant for general use, but in the case of aluminium alloys the addition of paraffin will be found beneficial in giving a better finish and preventing tearing of the threads.

Drills

In the small workshop, the provision of suitable drills and their proper maintenance is apt to be neglected, to the detriment of accuracy and efficiency in drilling.

Modern drills are extremely effective tools, but to perform well they must be kept really sharp and given proper working conditions.

Sharpening drills is described in Chapter VIII and drilling methods in Chapter VI.

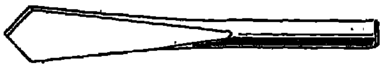


FIG. 12.

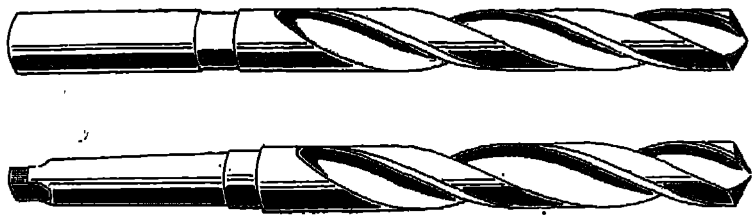


FIG. 13.

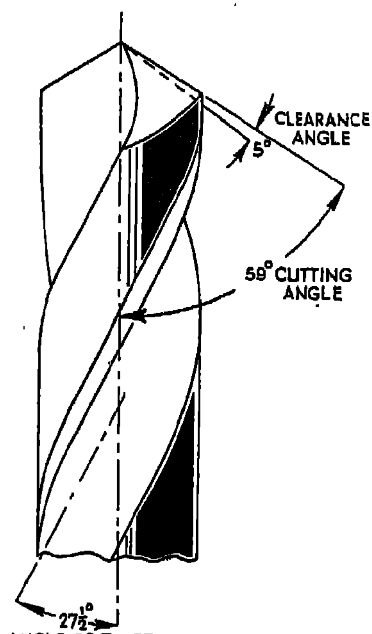


FIG. 13 (A).

The old form of drill for metal is the spear-pointed or flat drill shown in Fig. 12. This type of drill is made by flattening the end of a round bar of tool-steel and filing the point to

shape; it is then hardened and after tempering is sharpened on a grind-stone.

Although this type of drill is still occasionally used, it is very inefficient and is prone to wander out of alignment.

The Morse twist drill, of which two types are illustrated in Figs. 13 and 13A, is now universally used. The parallel shank type is suitable for light work up to ½ in., but the taper shank form is advisable for heavy duty over ⅜ in. diameter.

The taper shank drill has the additional merit that the overhang of the drill point beyond the drill spindle is reduced to a minimum. It will be seen that the tapered portion of the shank, which engages the female taper in the drill spindle, is provided with a tang or tongue to fit into a slot in the spindle and thus prevent rotation under load.

The accompanying table of drills gives details of all the available sizes from No. 80 to ½in.

It will be seen that the drills are designated by their inch, millimetre, letter and number sizes.

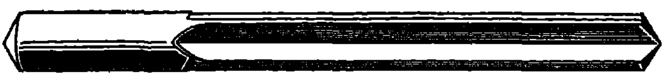


FIG. 14.

A full set of drills as shown in the table enables holes to be drilled from 0·013 in. diameter up to ½ in. diameter by small increments.

Standard twist drills have a cutting angle of 59 degrees, a clearance angle of some 5 degrees, and an angle of twist of 27½ degrees, although all these angles are subject to variation in the case of drills designed for cutting special materials such as plastics and some aluminium alloys.

Although the angle of twist cannot be altered except during manufacture, the cutting and clearance angles can be ground to suit special requirements, thus for drilling cast-iron a reduction of the cutting angle to 50 degrees or less is recommended, and in the case of brass a reduction of the clearance angle may lessen the tendency to dig into the work, but a better method is to grind or hone the front cutting edge to reduce the angle of rake as in the straight-flute drill.

Straight-fluted drills, as illustrated in Fig. 14, have no front or cutting rake, which renders them specially suitable for

TABLE OF TWIST DRILLS

Description	Size	Description	Size	Description	Size
	In.		In.		Ins.
No. 80	·0135	No. 35	·1100	Letter D	·2460
,, 79	·0145	,, 34	·1110	$\frac{1}{4}$ in. & Letter E	·2500
,, 78	·0160	,, 33	·1130	$6\frac{1}{2}$ m/m	·2559
,, 77	·0180	,, 32	·1160	Letter F	·2570
,, 76	·0200	3 mm.	·1181	,, G	·2610
,, 75	·0210	,, 31	·1200	$\frac{17}{64}$ in.	·2656
,, 74	·0225	$\frac{1}{8}$ in.	·1250	Letter H	·2660
,, 73	·0240	,, 30	·1285	,, I	·2720
,, 72	·0250	,, 29	·1360	7 m/m	·2756
,, 71	·0260	$3\frac{1}{2}$ mm.	·1378	Letter J	·2770
,, 70	·0280	,, 28	·1405	,, K	·2810
,, 69	·0292	$\frac{9}{64}$ in.	·1406	$\frac{9}{32}$ in.	·2812
,, 68	·0310	,, 27	·1440	Letter L	·2900
,, 67	·0320	,, 26	·1470	,, M	·2950
,, 66	·0330	,, 25	·1495	$7\frac{1}{2}$ m/m	·2953
,, 65	·0350	,, 24	·1520	$\frac{19}{64}$ in.	·2969
,, 64	·0360	,, 23	·1540	Letter N	·3020
,, 63	·0370	$\frac{5}{32}$ in.	·1562	$\frac{5}{16}$ in.	·3125
,, 62	·0380	,, 32	·1570	8 mm.	·3150
,, 61	·0390	4 mm.	·1575	Letter O	·3160
1 mm.	·0394	,, 21	·1590	,, P	·3230
,, 60	·0400	,, 20	·1610	$\frac{21}{64}$ in.	·3281
,, 59	·0410	,, 19	·1660	Letter Q	·3320
,, 58	·0420	,, 18	·1695	$8\frac{1}{2}$ m/m	·3346
,, 57	·0430	$\frac{11}{64}$ in.	·1719	Letter R	·3390
,, 56	·0465	,, 17	·1730	$\frac{11}{32}$ in.	·3437
,, 55	·0520	,, 16	·1770	Letter S	·3480
,, 54	·0550	$4\frac{1}{2}$ mm.	·1772	9 m/m	·3543
$1\frac{1}{2}$ mm.	·0590	,, 15	·1800	Letter T	·3080
,, 53	·0595	,, 14	·1820	$\frac{23}{64}$ in.	·3594
$\frac{1}{16}$ in.	·0625	,, 13	·1850	Letter U	·3680
,, 52	·0635	$\frac{3}{16}$ in.	·1875	$9\frac{1}{2}$ m/m	·3740
,, 51	·0670	,, 12	·1890	$\frac{3}{8}$ in.	·3750
,, 50	·0700	,, 11	·1910	Letter V	·3770
,, 49	·0730	,, 10	·1935	Letter W	·3860
,, 48	·0760	,, 9	·1960	$\frac{25}{64}$ in.	·3906
$\frac{5}{64}$ in.	·0781	5 mm.	·1968	10 mm.	·3937
,, 47	0·785	,, 8	·1990	Letter X	·3970
2 mm.	·0787	,, 7	·2010	,, Y	·4040
,, 46	·0810	$\frac{13}{64}$ in.	·2031	$\frac{13}{32}$ in.	·4062
,, 45	·0820	,, 6	·2040	Letter Z	·4130
,, 44	·0860	,, 5	)2055	$10\frac{1}{2}$ mm.	·4134
,, 43	·0890	,, 4	·2090	$\frac{27}{64}$ in.	·4219
,, 42	·0935	,, 3	·2130	11 mm.	·4331
$\frac{3}{32}$ in.	·0937	$5\frac{1}{2}$ mm.	·2165	$\frac{7}{16}$ in.	·4375
,, 41	·0960	$\frac{7}{32}$ in.	·2187	$11\frac{1}{2}$ mm.	·4528
,, 40	·0980	,, 2	·2210	$\frac{29}{64}$ in.	·4531
$2\frac{1}{2}$ mm.	·0984	,, 1	·2280	$\frac{15}{32}$ in.	·4687
,, 39	·0995	Letter A	·2340	12 mm.	·4724
,, 38	·1015	$\frac{15}{64}$ in.	·2344	$\frac{31}{64}$ in.	·4844
,, 37	·1040	6 mm.	·2362	$12\frac{1}{2}$ mm.	·4921
,, 36	·1065	Letter B	·2380	$\frac{1}{2}$ in.	·5000
$\frac{7}{64}$ in.	·1094	,, C	·2420		

drilling brass and sheet metal, for unlike twist drills they do not tend to dig or pull into the work, and, moreover, they have the advantage of maintaining alignment when drilling deep holes.

However, to ensure accuracy when deep drilling, a D-Bit should be used. This form of drill, which is usually made in

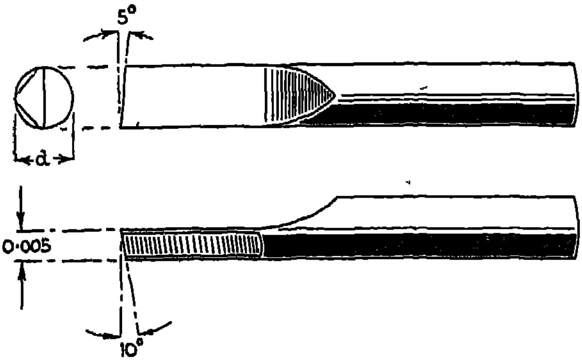
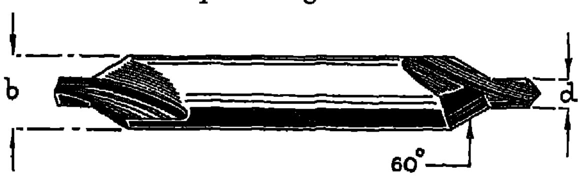


FIG. 15.

the workshop, is simply a length of round tool-steel finished on its diameter to the size of the hole required, and, as shown in Fig. 15, it is cut away almost to its diameter at the front end, which, to afford relief, is formed to a triangular section with narrow lands to provide guidance.



SIZE	WS1	WS2	WS3	WS4	WS5	WS6	WS7
BODY = b	$\frac{1}{8}''$	$\frac{3}{16}''$	$\frac{1}{4}''$	$\frac{5}{16}''$	$\frac{7}{16}''$	$\frac{5}{8}''$	$\frac{3}{4}''$
DRILL = d	$\frac{3}{64}''$	$\frac{1}{16}''$	$\frac{3}{32}''$	$\frac{1}{8}''$	$\frac{3}{16}''$	$\frac{7}{32}''$	$\frac{5}{16}''$

FIG. 16.

When operating this tool, an accurate guidance hole is first drilled to a depth equal to its diameter.

When using drills either in the lathe or in the drilling machine, a combination centre drill, as shown in Fig. 16, should first be

employed to form a coned recess to guide the cutting edges of the drill. This drill is also used to form the centre holes in work to be turned between centres in the lathe.

Countersinks and Spot-Face Cutters

In addition to the forms of drills already mentioned, there are others which are used for drilling operations.

In Fig. 17 are illustrated two forms of countersinks used for recessing holes to accommodate angular screw heads.

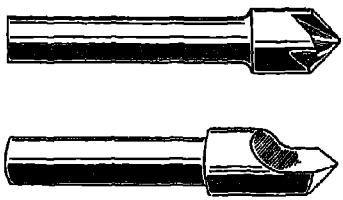


FIG. 17.

The type having a cutting face similar to that of the D-Bit is preferable owing to its freedom from chatter, whilst the multi-edged form, on the other hand, is apt to chatter unless run at slow speed.

The spot-face cutter depicted in Figs. 18 and 19 is used for facing lugs on castings for nut or screw head seatings, but the same tool will also serve for counterboring holes for bolt heads or cheese-headed screws.

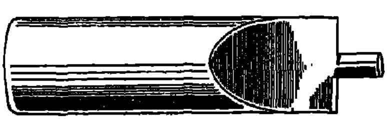


FIG. 18.

As will be seen, this cutter has two cutting edges and is provided with a guide pin to engage the drill hole.

The type shown in Fig. 18 is quite satisfactory for machining recesses up to half an inch in diameter; here, both the guide pin and the body are formed by turning in the lathe, and the cutting angles and the side relief are afterwards shaped by hand in accordance with Fig. 19.

For sizes larger than half an inch it is preferable to make the cutter itself out of a piece of tool steel, and the shank and guide pin component of mild steel. An abutment shoulder

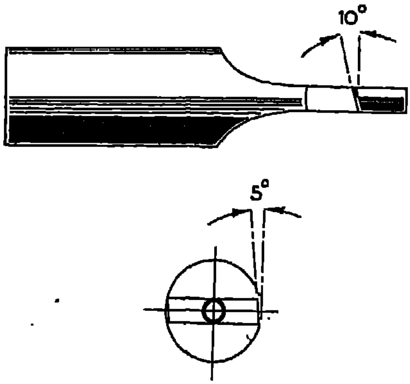


FIG. 19.

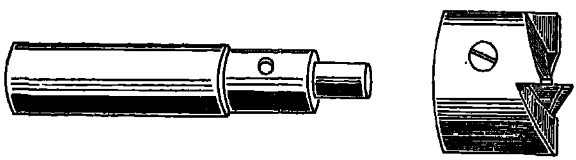


FIG. 20.

for the cutter is turned on the shank, and the cutter is secured in place by a grub-screw. The details of this device are illustrated in Fig. 20.

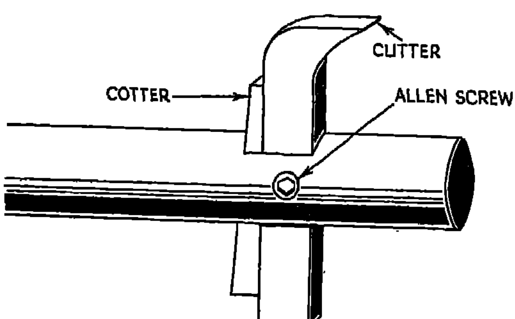


FIG. 21.

The Hole Cutter

Whilst not strictly a drill, the tool shown in Fig. 21 is widely used for cutting large holes in sheet metal. In using this tool

a centre hole to accommodate the shank is first drilled, and the cutter is then adjusted to the required radius and secured by the cotter and clamping screw. Owing to the great leverage imposed on the cutter bar it should be made from high-tensile steel.

End Mills

End mills of the type shown in Fig. 22 may be used in the drilling machine for counterboring or for forming recessed seats for screw heads, but in this case a hole rather less than the full depth required should first be drilled to afford guidance for the mill.

FIG. 22.

As commercial end mills are often made oversize, it may be preferable, for this purpose, to make two-lipped cutters of the type shown in Fig. 23 to the exact diameter required.

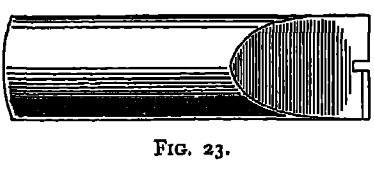


FIG. 23.

Reamers

Reamers are used for accurately sizing, and rendering parallel, holes which have previously been drilled or bored to within a few thousandths of an inch less than the finished size. It must be emphasized that reamers are not intended to remove large amounts of metal.

The amount of material left for removal by reaming may be no more than two thousandths of an inch in small holes, and, in any case, should be no more than is required for the formation of a true hole and the removal of previous tool marks.

Inspection of catalogues will show that a great variety of reamers is available, but in the small workshop only a few

types are required, namely, parallel hand reamers which may also be used in a machine, parallel adjustable reamers, Morse taper reamers, taper pin reamers, and broaches.

Hand Reamers

Fig. 24 shows a standard parallel hand reamer with straight flutes, but the spiral-fluted type is preferable as it has less tendency to chatter or to cut a multi-sided hole, although these

FIG. 24.

errors usually arise from the removal of too great a quantity of metal, particularly in the case of hard bronze.

When fitting shafts to bearings, it will be appreciated that, unless some means of packing the reamer is resorted to, it may not be possible to open up the bored bearing hole to fit the

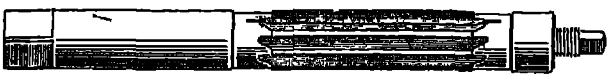


FIG. 25.

journal, and although there are many ways of carrying out this packing procedure, none is really satisfactory in practice or sound in theory.

Instead of this makeshift method, expanding reamers of the types shown in Figs. 25 and 26 should be employed.

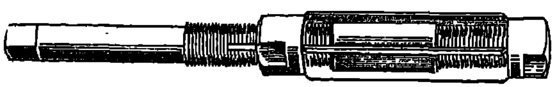


FIG. 26.

As will be seen in Fig. 25, an expanding reamer is similar externally to a parallel hand reamer, but within, it is hollow and has a long internal taper in which the tapered adjusting screw at the right-hand end can operate.

In addition, there are three or more narrow slots in the body of the reamer which allow it to expand under the influence of the adjusting screw.

It will be appreciated that the range of expansion of this type of reamer is very limited, and no attempt should be made to expand it more than is specified in the following table.

Reamer diameter	Permissible expansion
$\frac{1}{4}$ in. to $\frac{15}{32}$ in.	0·005 in.
$\frac{1}{2}$ in. to $\frac{31}{32}$ in.	0·008 in.
1 in. to $1\frac{23}{32}$ in.	0·010 in.
$1\frac{3}{4}$ in. to 2 in.	0·012 in.

These reamers are excellent for high-class fitting, for they are easy to use and can be set to an exact size with the aid of a micrometer.

Largely on account of the limited range of expansion of these reamers and the high cost of a set adequate for all purposes, the type of reamer shown in Fig. 26 has been produced.

Here, the blades are quite separate from the body, which has inclined guide-ways up which the blades travel under the pressure exerted by the adjusting collars.

Reamers of this class have a wide range of adjustment varying from $\frac{1}{32}$ in. in the $\frac{1}{4}$ in. reamer to $\frac{5}{16}$ in. in the case of the $2\frac{1}{4}$ in. reamer, which is the largest of the series.

It is not mechanically possible to provide a large number of cutting blades in an expanding reamer of this form, and there are but five blades as against the eight cutting edges of the other type. As a result, more care in operation is required to obtain the best results.

On the other hand, the cutting edges of the five-blade type remain parallel throughout the range of expansion, whereas in the other form the blades are parallel, in theory at least, at only one position of the setting.

It should be emphasized that the above two types of expanding reamers are suitable for hand use only and should not be used in a machine.

Machine Reamers

If extensive machine reaming is contemplated, it is advisable to use tools specially designed for the purpose.

In the case of plain reamers, some manufactures recommend the type illustrated in Fig. 27; these may be obtained with either parallel or Morse taper shanks.

It will be seen that the reamer portion is much shorter than in the hand reamer; this makes the tool eminently suitable for use in chucking operations such as the manufacture of bushes, in which the length of the bore is usually short.

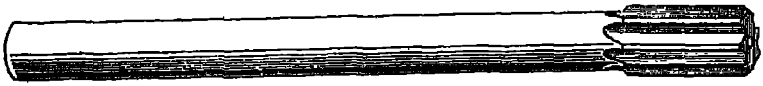


Fig. 27.

If, on the other hand, long bores or bushes in line have to be reamed, it will be advisable to use reamers of the hand pattern provided with Morse taper shanks.

In the case of machine reamers of the expanding type a wide choice is available, and in Figs. 28 and 29 two views are

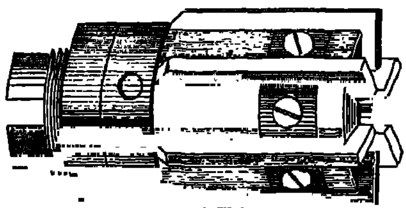


Fig. 28.

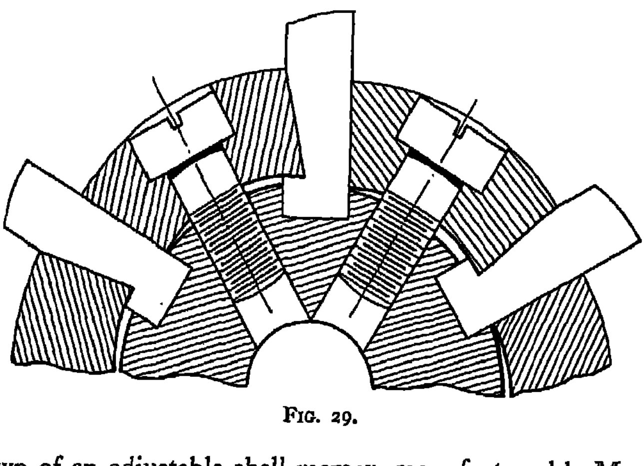


Fig. 29.

shown of an adjustable shell reamer, manufactured byMessrs. Pratt & Witney, which is typical of this class.

To set these reamers to the required size, it is only necessary to loosen the shoes and slacken the nuts to allow the blades to

be pushed back. The adjusting nut is then tightened until the required size is obtained, and the locknut and shoe screws are secured to complete the operation. The range of these reamers is from $1\frac{3}{16}$ in. to 4 in. in twelve sizes.

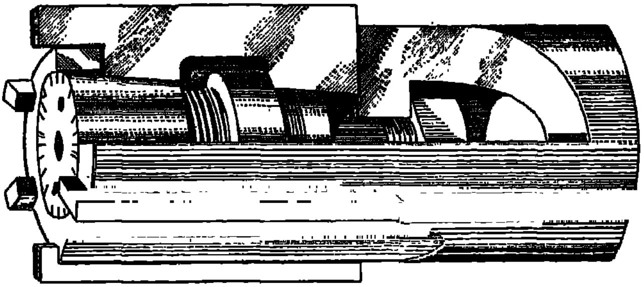


FIG. 30.

Fig. 30 shows a section of the Vickers adjustable reamer in which the adjustment for size is effected by turning the graduated cone bolt. The range here is from $\frac{5}{8}$ in. to 6 in. in the case of the largest reamer.

Morse Taper Reamers

These reamers are used for the final finishing of holes which have previously been bored to a standard Morse taper. A

FIG. 31.

reamer of the usual commercial type is illustrated in Fig. 31, and, as will be seen, it is of the hand pattern, which is commonly used as only very fine cuts should be taken when finishing these taper bores.

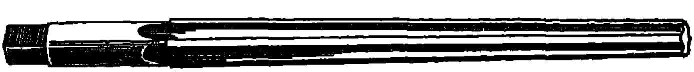


FIG. 32.

Taper-Pin Reamers

These reamers are made for fitting the various sizes of standard taper pins, and an example is illustrated in Fig. 32.

Standard taper pins have a taper of $\frac{1}{4}$ in. per foot, and the reamers are ground correspondingly.

Formerly, the range of these reamers was from No. 0 to No. 9 with entry diameters of 0·127 and 0·482 respectively, but now reamers designated No. 000000 are made with an entry diameter of 0·0606.

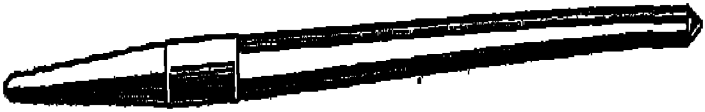


FIG. 33.

The five-sided taper broach depicted in Fig 33 is sometimes used for seating small taper pins, but it is comparatively slow-cutting, and is apt to wander out of alignment if forced when in operation.

CHAPTER IV

DRIVING MACHINE TOOLS

Independent Electric Motor Drives. Prime Movers. Installation of Engines. Line Shafting. Pulleys. Countershafts and Belt Shifts. Pulley Calculations. Belts. Belt Calculations. Lathe Overhead Driving Gear. Driving Bench-Mounted Machine Tools.

THERE are two methods of driving machine tools; in the first, a prime mover drives a common line-shaft from which the power is distributed to the individual machines by pulleys and belts.

This practice is falling into disuse, even for the smallest installations, on the score of relatively high first cost, noise, difficulties of upkeep and, especially in the case of commercial undertakings, waste of space and loss of daylight occasioned by the multiplicity of belts necessary in such a system. A further disadvantage of the line-shaft drive, particularly in the small workshop, is that the whole power system must be put in motion even if the brief use of only a single machine is required.

However, as the system is still much used it will later be considered in detail.

Independent Electric Motor Drives

The alternative method, which is rapidly gaining ground as it overcomes all the objections to the first system, is to equip each machine tool with an electric motor from which it is driven by gears, chains, or belts.

The modern practice is to build the electric motor directly into the machine, and in some instances machines are equipped with subsidiary motors for actuating feed gears and other movements, for the cost of the extra motors is usually less than the expense involved in installing the alternative mechanical gear.

As electric power is now usually available at comparatively low cost, this system of Independent Motor Drive, as it is termed, has much to recommend it, and moreover, for the older types of machine tools which are not equipped with built-in motors, it is now possible to purchase motorizing units which are easily installed.

Even in localities where there is no source of electric power, or its cost is prohibitive, it is still possible to adopt the system of independent motor drive by installing a generating set to provide the electric current.

Where the system of independent motor drive is adopted at the outset, no installation difficulties will be encountered, for the makers supply their machine tools fully equiped with suitable electric motors, and it is only necessary to connect up to the workshop mains through the appropriate starting switch and double-pole switch-fuse unit.

In large shops it is usual to provide connector or tapping-off boxes at convenient places in the machine bays in order to shorten the length of the connecting cable, but in small workshops it is usually better to position this box at some easily accessible central point.

The maintenance of the modern electric motor, particularly those for use on A.C. supply, has been reduced to a minimum; for lubrication has become largely automatic, with the necessity to replenish oil containers at long intervals only, and attention to the brush gear, where fitted, is but seldom required. Nevertheless, periodic routine inspection is still necessary, if only to prevent unforeseen failures.

Prime Movers

In the case of the line-shaft method of driving, where an electricity supply is available, an electric motor of suitable capacity should be installed as the power unit, but, on the other hand, where there is no electric power the choice will almost certainly fall on an internal combustion engine, either gas, petrol, paraffin or Diesel.

In some instances steam power may be considered, and may be found economical for use in commercial undertakings where steam boilers are required in connection with some industrial processes, but the difficulties of operating and supervising a steam plant usually preclude its use in the small workshop.

Modern internal combustion engines are usually of the totally-enclosed type, a feature which protects the working parts from the abrasive dust of the workshop and obviates the former necessity of installing the engine in a room apart.

In addition, this design usually embodies an automatic system of lubrication which greatly reduces the need for attention to the engine when in operation.

When selecting an internal combustion engine there are several factors which should be considered:

1. The speed and horse power at which the engine is required to work.
2. The direction of rotation. Most makers supply their engines for anti-clockwise rotation when viewed from the fly-wheel end, but clockwise rotation can usually be provided if required.
3. Cooling. The manufactures should be informed if the engine is required for use in tropical climates or at high altitudes.
4. Air cleaning. Engines used in dust-laden air should always be fitted with efficient air-cleaning devices. Felt air-cleaners are suitable for average dirty conditions, but an oil-bath air-cleaner should be used where abrasive dust is present.

Particular attention should be paid to the design of the exhaust system, and if for any reason it becomes necessary to depart from the manufacturer's normal arrangement their advice should be sought, otherwise the efficient working of the engine may be impaired.

In the development of the modern medium-powered industrial engine, with but few exceptions, the trend of design has been towards the vertical type.

In practice, this design has the two-fold advantage of reducing the space required for installation and minimizing piston and cylinder wear in the heavier types of engines.

Although there are many well-designed and efficient small engines now available, it is not possible here to mention more than a few.

Messrs. R. A. Lister & Co. produce a range of industrial engines for petrol, petrol-paraffin and also Diesel types extending from 1 h.p. to 40 h.p., all of which may be fitted with alternative forms of power take-off to suit particular working

conditions. In addition, three forms of water-cooling are available, namely, hopper, tank and radiator cooling.

Fig. 1 illustrates the Lister tank-cooled engine with an output of 1 h.p. at 1,000 revolutions per minute.

Of late years, the use of air-cooling for stationary petrol engines of medium power has been widely developed, and this is particularly the case where light-weight engines are

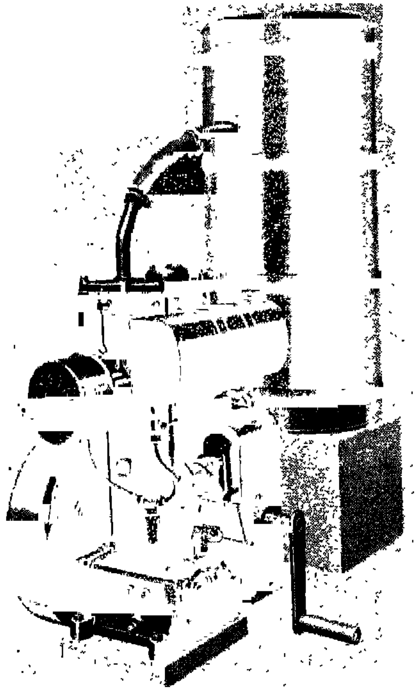


FIG. 1.—Lister Tank-cooled Engine.

required for portable use, although this in turn necessitates the engines being of the high-speed type and developing their power at from 1,800 to 3,000 revolutions per minute.

As this type of engine is excellent for intermittent duty, it may be selected for use in the small workshop by reason of its low first cost and ease of installation.

Manufacturers of such engines are Messrs. J. A. Prestwich & Co., the Villiers Engineering Co. and the Norman Engineering Co.

Fig. 2 illustrates the J.A.P. power unit which delivers 1 h.p. at 2,000 revolutions per minute.

If a high degree of silence and smoothness of running is desired with the air-cooled engine, the flat-twin form of engine is recommended owing to its superior balance.

A notable example of this type is the horizontally-opposed flat-twin engine manufactured by the Norman Engineering

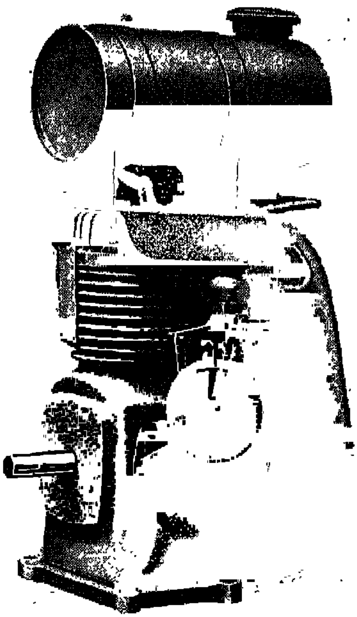


FIG. 2.—J.A.P. Power Unit.

Co. and depicted in Fig. 3. Although originally designed as a portable engine, it can now be obtained mounted on a bed-plate provided with an A-bracket carrying a ball bearing to relieve the crankshaft from radial load.

The fitting of this bearing is not strictly necessary as the main crankshaft bearings are well able to withstand any radial load within the capacity of the engine, whose output is $2\frac{3}{4}$ h.p. at 1,800 revolutions per minute.

Installation of Engines

The amount of space available in the workshop will inevitably decide the allowance apportioned for the installation of the engine, but the reliability of the modern small engine is

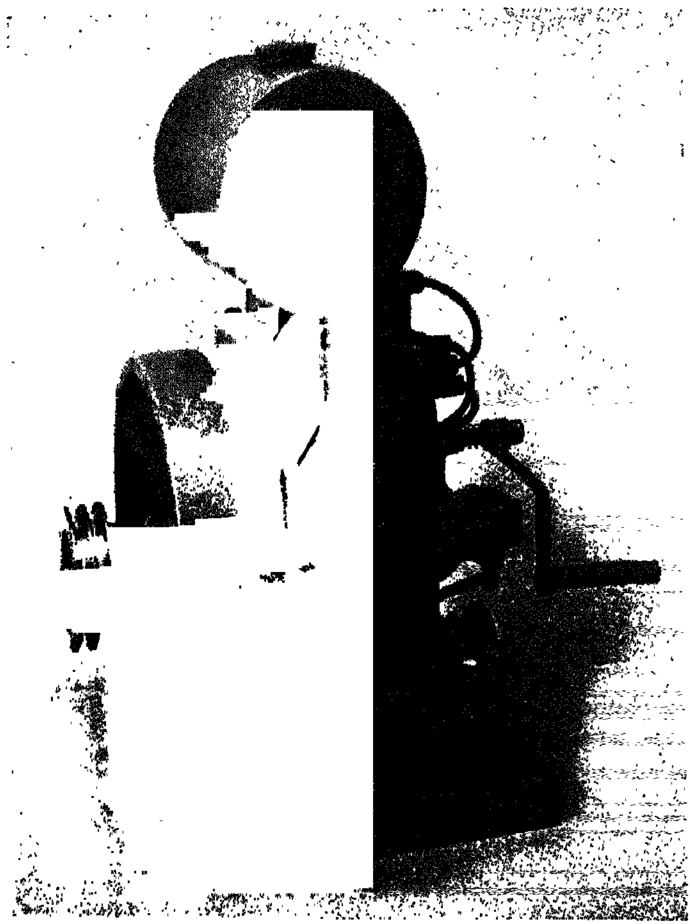


FIG. 3.—Flat-twin Engine. (Norman Engineering Company.)

such that it is not necessary to provide more space than is required to carry out routine maintenance work.

A larger power plant, however, may be housed in a separate room to facilitate inspection and attention when required.

Whether the installation be large or small, two points require particular attention, namely, the engine foundations and the exhaust system.

With regard to the former, it is advisable, particularly in the case of a high-speed engine, to mount the power unit on a substantial concrete block in order to absorb any vibration that might otherwise be transmitted to the building.

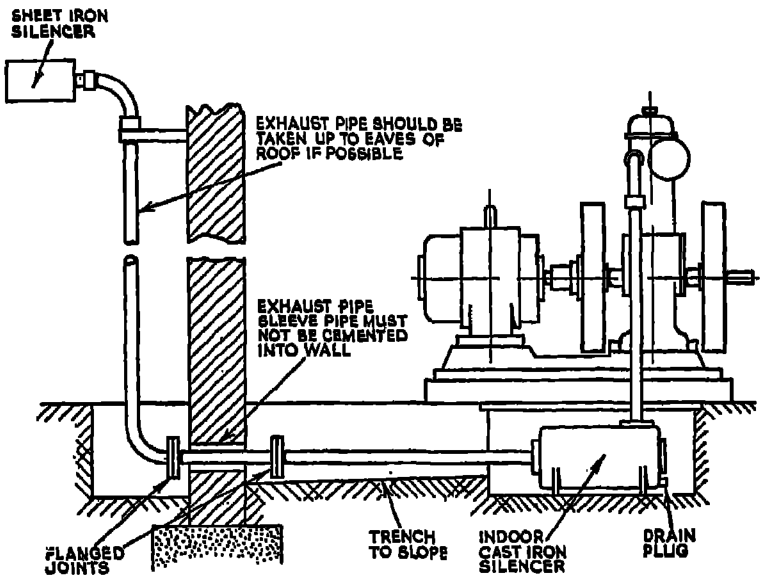


FIG. 4.—Arrangement of Exhaust System.

On the other hand, where circumstances preclude such a mounting, engines of the portable type will run quite satisfactorily if mounted on substantial wooden runners bolted to the concrete floor.

It should, however, be emphasized that the first method is to be preferred, especially where the installation is of a permanent nature.

The manufacturers of the engine selected will provide a drawing showing the centre distances and sizes of the holding-down bolt holes, and also any further relevant information to enable the purchaser to prepare the foundation.

It is better not to attempt to concrete the holding-down bolts in place before the engine is mounted on its bed, but chases should be left so that the bolts can be slipped into place as the engine is being mounted, after which the bolts are grouted in with sharp cement.

If the engine is to be used in the vicinity of dwelling houses careful attention should be paid to the silencing of the exhaust system. Effective silencing does not necessarily entail an inefficient exhaust system, for the solution of the problem depends on the provision of expansion boxes of ample size, and exhaust pipes of adequate dimensions.

The exhaust system should conform generally to the arrangement shown in Fig. 4, but, as this may be rather elaborate for small installations, modifications should be made as circumstances dictate.

It should be emphasized that, as water is one of the products of combustion, the design of the exhaust system should provide for the escape of any condensate that may tend to collect.

If this is not possible, then provision must be made for drainage by means of a removable plug as shown in the drawing, but experience shows that this is more often necessary with small rather than large engines, where the volume of the hot exhaust gases is sufficient to evaporate the condensate.

Line Shafting

Formerly, the workshop line-shaft, from which the various machines were driven, was carried in bearings of the simplest possible construction.

These bearings, or plummer blocks as they are termed, contained split bronze shells held in a cast-iron body by a cap secured in place by studs and nuts, but although easily installed, these bearings were the cause of much loss of power due to friction.

Even when the brackets carrying the bearings were accurately lined up in the first instance, the radial loading caused by the weight of the shaft itself was usually sufficient to cause loss of alignment with excessive bearing friction and heating of the journals and bushes.

When the economical and efficient operation of workshops and factories came to be studied, such a state of affairs could not be tolerated, and as a result many types of bearings were designed in an attempt to reduce bearing inefficiency.

Although some of these, particularly the self-aligning types, gave better operation, they were still not entirely satisfactory and caused undue friction when under load owing to the fact that plain bearings were used.

It had been appreciated for some time that a high shaft speed was essential to ensure the greatest economy and efficiency in running, and it was not until a practical method of making and fitting ball-bearings had been devised that it was possible to obtain satisfactory operation.

As an indication of the saving of power when ball-bearings were fitted, gains of from 15 per cent. to 35 per cent. were recorded, whilst the saving of lubricant and maintenance costs was in some instances as high as 97 per cent.

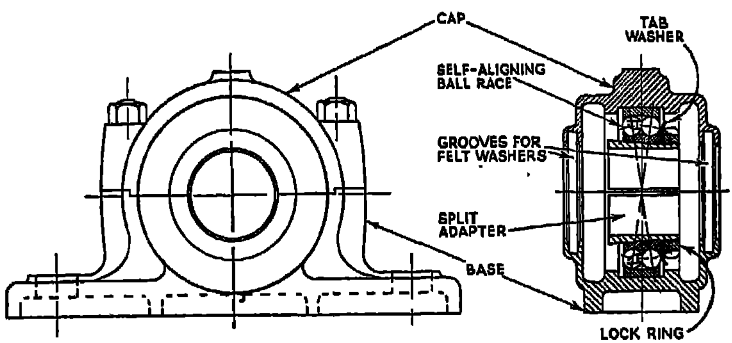


FIG. 5.

Owing to the increased line-shaft speed possible when ball-bearings are used, smaller pulleys can be employed, and when machines have to be speeded up it is often then possible to dispense with countershafts, thus effecting considerable economy.

Figs. 5, 6 and 7 show typical Ball and Roller Bearing Plummer Blocks made by the Skefko Ball Bearing Co. It will be seen that these comprise a split housing in which the outer bearing race is held. The ball-bearings fitted are of the self-aligning type and have a tapered bore into which a split adapter is fitted. This adapter is contracted on to the shaft, when the bearing is fitted, by the action of a ring nut pulling the adapter into the tapered bore of the bearing. As a safeguard against the ingress of dirt, and to retain the lubricant within the bearing, felt rings are fitted into grooves machined in the housing.

The whole arrangement is simple in itself and forms the basis of all the types of line-shaft equipment manufactured by the Skefko Co.

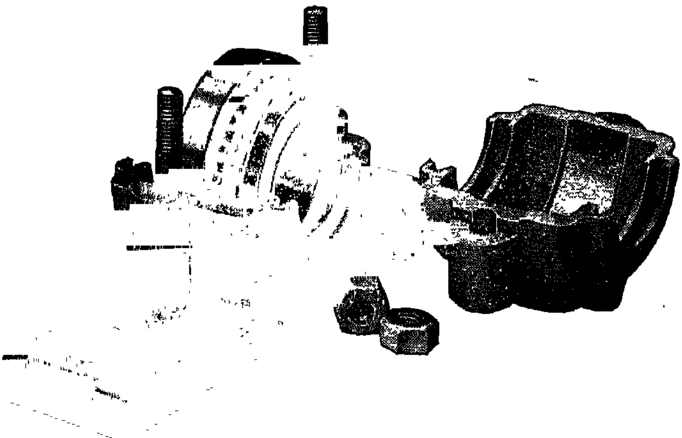


FIG. 6.

Space does not permit a fuller description of the construction and application of these bearings, but if further information is desired reference should be made to the excellent publications on the subject issued by the manufacturers.

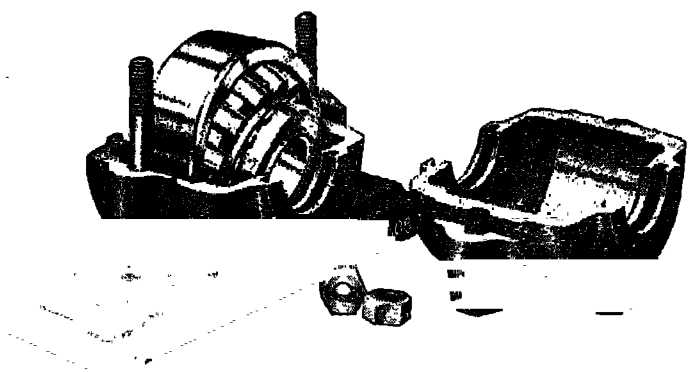


FIG. 7.

Pulleys

Reference to the catalogues of machine-tool dealers will show that there is a great variety of pulleys available for all purposes. These range from small solid cast-iron forms to metal and wooden split pulleys of larger diameter. The split

pulley is the most practical type for use with line-shafting, as it can be fitted and removed from the shaft without disturbing the bearings or other pulleys already in place, and, in addition, as it usually well-balanced and lighter than the solid type it is suitable for fitting to high-speed shafting.

Although this type of pulley will transmit all normal loads by virtue of the gripping power of the hub on the shaft, as an additional means of security the larger sizes are made with a keyway to provide positive fixing to the shaft should this be found necessary.

In addition, adapters in the form of split bushings can be obtained to fit any size of shaft.

As an alternative to the cast-iron pattern, the wooden split pulley may be considered as it is not only comparatively cheap but can be relied on to give satisfactory service. These pulleys are usually of laminated construction and several forms are obtainable, but care should be taken to ensure that they remain firmly fixed and do not loosen on the shaft owing to contraction and expansion of the wooden material. Laminated wooden pulleys are readily made by amateur mechanics as articles appearing from time to time in the *Model Engineer* will testify.

Countershafts and Belt Shifts

For driving machines that are not provided with a built-in clutch mechanism it is necessary to employ a countershaft, interposed between the line-shaft and the machine.

The function of the countershaft is twofold: it has to provide a ready means of starting and stopping the machine, and it also acts as a gear-changing mechanism for altering the relative speeds of the line-shaft and the machine spindle.

Fig. 8 shows a typical countershaft arrangement which comprises two inverted A-brackets carrying bearings to support the shaft. In addition, the A-brackets carry the belt striking gear which is operated by cords dependent from the crank disc. The latter method of operation is not recommended as there is the danger that in an emergency the wrong cord may be pulled.

The more usual and more certain method of moving the striking gear is by a lever, pivoted at some convenient point, actuating the sliding bar to which the belt fork is attached.

Moreover, for the sake of safety, a frictional mechanism should be provided to retain the lever in the free position,

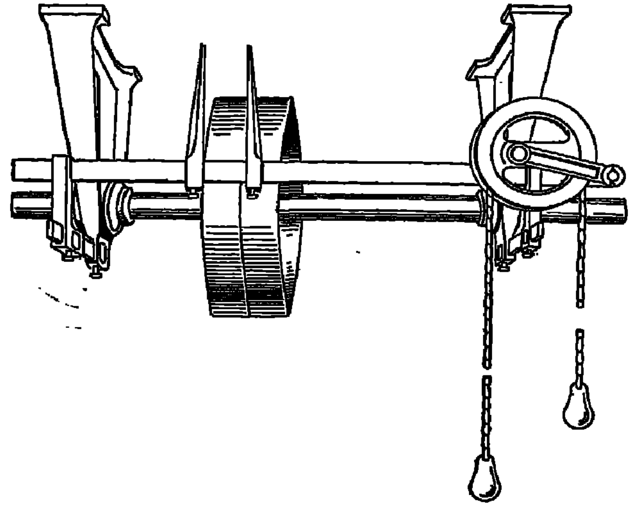


FIG. 8.—Countershaft Arrangement.

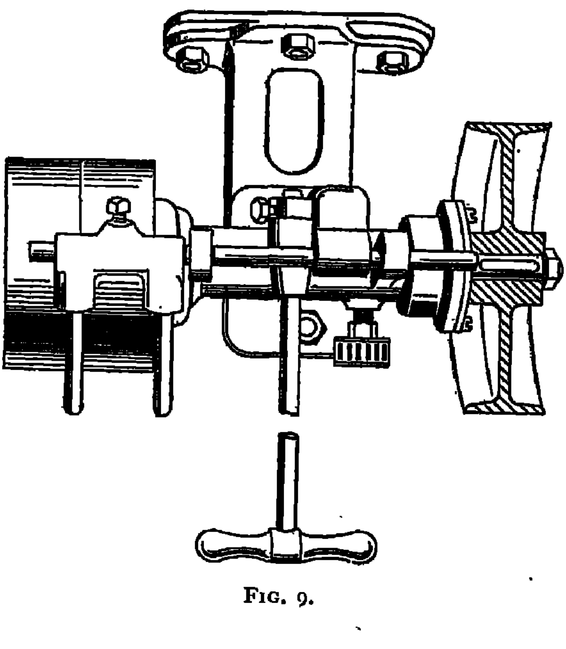


FIG. 9.

otherwise there is the possibility of the belt creeping on to the fast pulley and starting the machine while the work is being handled.

This type of countershaft is suitable for driving the larger machine tools such as lathes and shaping machines, but for the lighter machines a more compact form of countershaft is an advantage.

The type illustrated in Fig. 9 will indicate the general design of these units which are self-contained and easy to instal. The more expensive types are fitted with ball-bearings, but

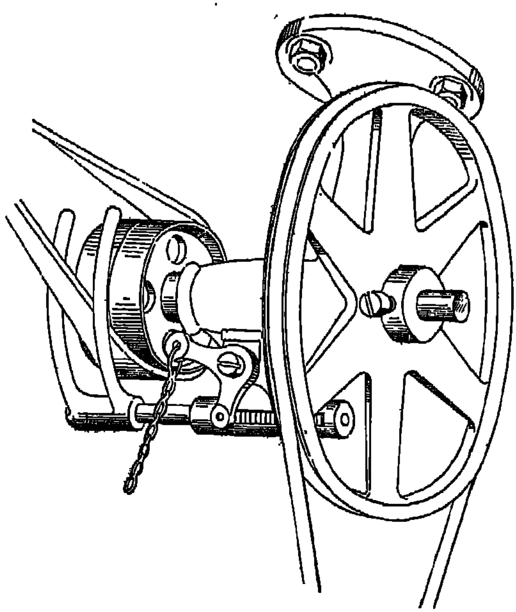


FIG. 10.

the cheaper forms, although provided only with plain bearings, are quite satisfactory for intermittent duty.

A useful form of countershaft of Swiss manufacture and designed for foot operation is shown in Fig. 10.

Here, the main spindle, which is hardened and ground, runs in cast-iron bearings equipped with ring-oilers fed from a central oil well formed in the main casting.

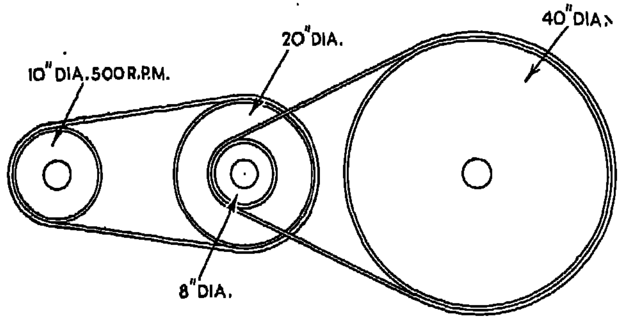
An interesting point of design is that the loose pulley also

has an oil well formed in its casting; this feeds the oil to the shaft bearing by centrifugal force when the countershaft is in use.

The belt-shipper is spring-loaded in order to return the belt to the loose pulley when the foot pedal is released.

Pulley Calculations

In any system of pulleys or gears, the rule is that the product of the diameter (or number of gear-teeth) and the number of revolutions of the first driver equals the product of the diameter (or number of gear-teeth) and the number of revolutions of the last driven wheel.



EXAMPLE.

The following are examples of this rule:

$$\text{Revs. of driven wheel} = \frac{\text{Diam. of driver} \times \text{revs. of driver}}{\text{Diam. of driven}}$$

$$\text{Diam. of driven} = \frac{\text{Diam. of driver} \times \text{revs. of driver}}{\text{Revs. of driven}}$$

$$\text{Revs. of driver} = \frac{\text{Diam. of driven} \times \text{revs. of driven}}{\text{Diam. of driver}}$$

$$\text{Diam. of driver} = \frac{\text{Diam. of driven} \times \text{revs. of driven}}{\text{Revs. of driver}}$$

To find the speed when three or more shafts are connected by belts: multiply the number of revolutions per minute of the first driver by the diameters of each driver in turn and divide the product by the product of the diameters of the driven pulleys.

The quotient, so obtained, will be the number of revolutions per minute of the last driven pulley.

For example, three pulleys are connected by belts, and the driving pulley of 10 in. diameter rotates at 500 revolutions per minute. The second or driven pulley is 20 in. diameter, and the second driver pulley is 8 in. diameter. The final driven pulley is 40 in. diameter.

$$\text{Then,}\quad \frac{10 \times 8 \times 500}{20 \times 40} = \frac{400}{8} = 50 \text{ revs. per minute.}$$

Belts

Round belts. Formerly, round catgut belting was widely employed for driving treadle lathes, but this material is now seldom used except for very light drives.

These belts were joined by a hook and eye fastener attached to the ends of the belt by means of a coarse screw thread. When in place the fasteners were further secured by searing the ends of the belt to expand the catgut.

A twisted flat strip of raw-hide will form a round belt with a hollow centre, and although this has the advantage of being readily shortened by further twisting, there is no very satisfactory form of belt fastening available.

A steel coil-spring belt is sometimes used for light drives, but it is inclined to be noisy at high speeds, and the piece of screwed rod used as a fastener forms a rigid place in the belt.

Endless round belts made of rubberized canvas can be obtained. These are quiet running and have a long working life.

For light drives perhaps the most widely-used type of round belt is the solid form with the ends joined by a steel wire hook-fastener.

The commercial sewing machine belt is excellent for light high-speed drives as it is very flexible and is made from leather of good quality. Messrs. Houghtons' "Vim" round leather belting is of the highest quality and is supplied in sizes from $\frac{1}{8}$ in. to $\frac{1}{2}$ in. diameter.

The obvious disadvantages of using a hook or other type of fastener for small belts can be largely overcome by careful fitting. In the smaller sizes of round belts, the holes to receive the limbs of the hook should be bored with an awl in order to separate and not cut the fibres, as would happen if the holes were drilled.

The ends of the belt when the fastener is finally closed must butt together firmly, otherwise the leather will work on the fastener, thus causing wear and leading to breakage.

Although it is more trouble to make, a cemented and stitched scarf joint will sometimes be found preferable, for the belt so joined is equally flexible throughout its length and will run smoothly and without causing noise or vibration.

If possible, a cement of the cellulose type should be used to ensure flexibility of the joint.

Formerly, V-pulleys for round belts were machined with an included angle of 90 degrees, and although this is suitable for jockey or guide pulleys, drive pulleys grip the belt more firmly when the V is machined to an angle of 60 degrees or less.

Flat belts. The rubberized canvas belt is widely used as it is cheap and affords an efficient drive, particularly under adverse conditions of moisture and dirt.

As any form of lacing is apt to pull through the cotton fibres, a metal fastening of the multi-tooth type with a joint pin is commonly used, and although these fasteners are very efficient, they tend to cause a click when meeting the surface of a revolving pulley.

The endless form of belt is manufactured in this material, but adequate means of adjustment to overcome stretching in use should be provided.

Best quality leather belts such as the "Vim," although more expensive, are most satisfactory in service if properly installed and maintained.

If desired, a cemented and stitched scarfed joint can be used to form an endless belt, but, on the other hand, a thoroughly reliable joint can be made with wire stitching, or with leather lacing in the case of a wide belt.

Fig. 11 represents the back of a 1 in. wide leather belt with the ends joined by two stitches of 20 gauge copper or soft iron wire.

To make this form of joint the ends of the belt are first cut accurately square, then the centres of the stitch holes are marked-out at a distance from the ends of one and a half times the thickness of the belt.

The holes may be pierced conveniently with a fine scriber.

The stitches must be tightened to butt the ends of the belt closely together and to maintain its edges in alignment.

For wider belts the number of stitches may be increased to afford adequate holding.

After tightening the stitches, the joint should be pressed in the vice with a piece of cardboard against the back of the belt and a strip of metal against the working face; this will press the stitches into the leather and the belt will run silently. Hammering should be avoided as this may cause elongation of the wire stitches and gaping of the joint.

V-belts. Endless V-belts are rapidly displacing flat belts for machine tool driving as they have many outstanding advantages. With this type of belt even short drives from small to large pulleys can be employed without fear of slip; the drive even at high speeds is almost silent; the belt will drive efficiently when loose, thus reducing bearing loads; the drive requires

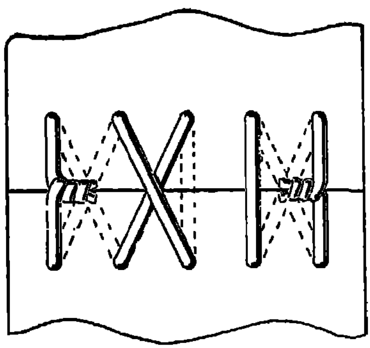


FIG. 11.

hardly any attention and will operate satisfactorily under unfavourable conditions; furthermore, these endless belts can be obtained as standard in any reasonable length and their cost is small.

To provide for quick belt shifting with step pulleys, these belts require a swinging form of countershaft with belt tension stop, but where only occasional belt changes have to be made an adjustable type of countershaft may be sufficient.

Tilting bases for mounting electric motors can be obtained; these have the great advantage of allowing the belt tension to adjust itself according to the load, thus minimizing bearing wear and preventing belt slip.

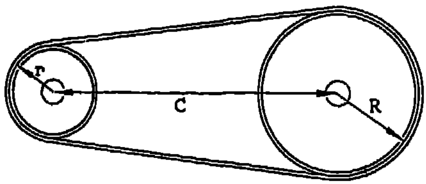
When the drive is taken from a small to a large pulley, the latter will afford sufficient belt grip if it has a plain flat driving face, provided that the arc of belt contact is adequate.

As the angle of the V varies somewhat in different makes of belts, the manufacturers' instructions should be followed when purchasing or machining V-pulleys.

When calculating the gear ratio of a V-belt drive, measure the pulley diameters at the pitch line of the belt, that is to say, determine the outside diameter of the belt on the pulleys and subtract the thickness of the belt in each case.

Belt Calculations

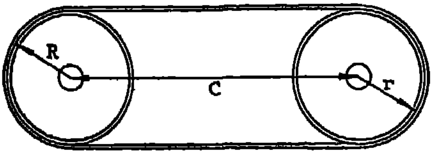
(1) *Flat Belts.*—To find the length of belt required for two pulleys of unequal diameter.



$$L = \pi (R + r) + 2\sqrt{c^2 + (R - r)^2}$$

Where L = Length of belt
R = Radius of large pulley
r = Radius of small pulley
c = Centre distance.

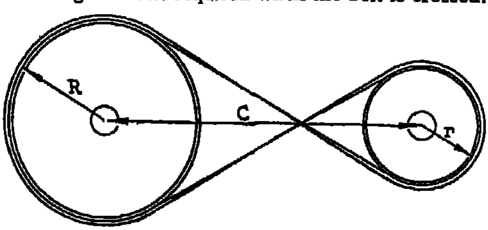
(2) To find the length of belt required for two pulleys of equal diameter.



$$L = \pi (R + r) + 2c.$$

Where L = Length of belt
R = Radius of either pulley
r = Radius of either pulley
c = Centre distance.

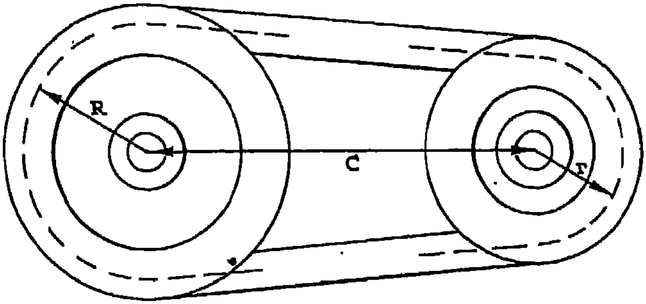
(3) To find the length of belt required when the belt is crossed.



$$L = \pi (R + r) + 2\sqrt{c^2 + (R + r)^2}.$$

Where L = Length of belt
R = Radius of large pulley
r = Radius of small pulley
c = Centre distance.

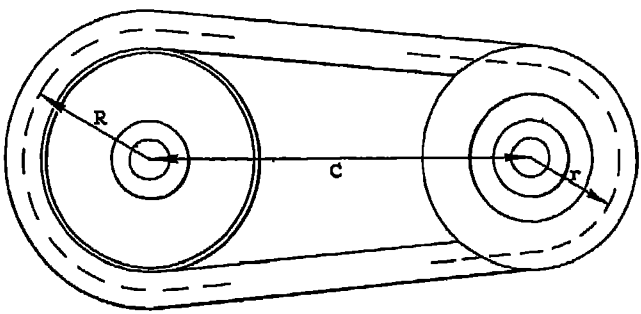
(4) *V-Belts.*—To find the length of belt required for two V-pulleys.



$$L = \pi(R + r) + 2\sqrt{c^2 + (R - r)^2}$$

L = Length of belt
R = Radius of large pulley less half the thickness of the belt
r = Radius of small pulley less half the thickness of the belt
c = Centre distance.

(5) To find the length of belt required for a V-pulley and a flat pulley.



$$L = \pi(R + r) + 2\sqrt{c^2 + (R - r)^2}.$$

L = Length of belt
R = Radius of large pulley plus half the thickness of the belt
r = Radius of small pulley less half the thickness of the belt
c = Centre distance

Lathe Overhead Driving Gear

When using milling and drilling devices in conjunction with the lathe, the drive is usually taken from a countershaft specially installed for the purpose, although the countershaft employed for driving the lathe may sometimes be used in this way.

For this purpose, it may be necessary to fit an extension shaft to the countershaft to enable it to carry a driving pulley in line with the milling attachment, and at the same time the lathe belt must be held clear of its driving pulley.

If, on the other hand, a separate countershaft for occasional use only is required, this may take the form of a simple driven shaft equipped with a driving pulley sliding on a key, but as the longitudinal movement required during milling operations will probably be small, it may be sufficient to align the driving pulley and then secure it to the shaft by means of a locking bolt.

In an overhead of this type no provision is made for the automatic adjustment of the belt tension, but this will be found no great disadvantage if the milling attachment has some means of setting the belt tension, for the small round leather belts

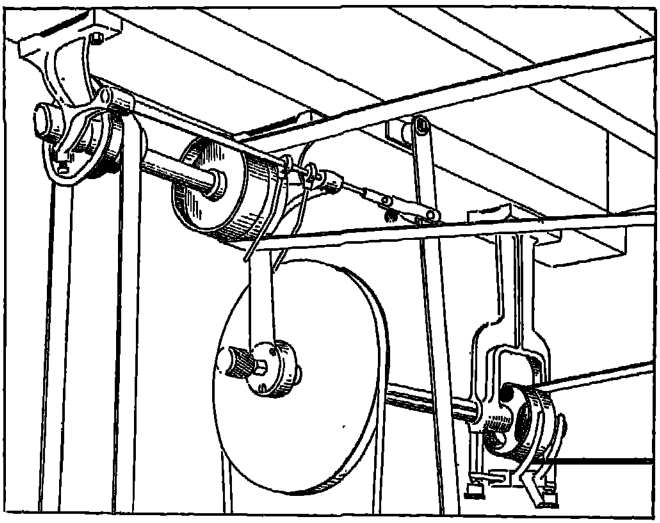


FIG. 12.

commonly used have sufficient elasticity to accommodate the relatively small vertical movement involved. An overhead gear of this type with a large driving pulley is illustrated in Fig. 12.

Should it be found, however, that a greater range of movement during the machining operation is required, this can be provided for by fitting the milling attachment with a spring-loaded jockey pulley, bearing on the slack or non-tension part of the driving belt.

In the small professional workshop, on the other hand, it may be advisable to instal an overhead fitted with an automatic belt tensioning device, as this will greatly facilitate setting the drive for the milling attachment.

The well designed Drummond overhead gear supplied for the 3½ in. lathe is illustrated in Fig. 13, and, as will be seen, this comprises two heavy tubular uprights carrying both the driving shaft and the tie bar, to which the belt tensioning device with its counterweight and guide pulleys is attached.

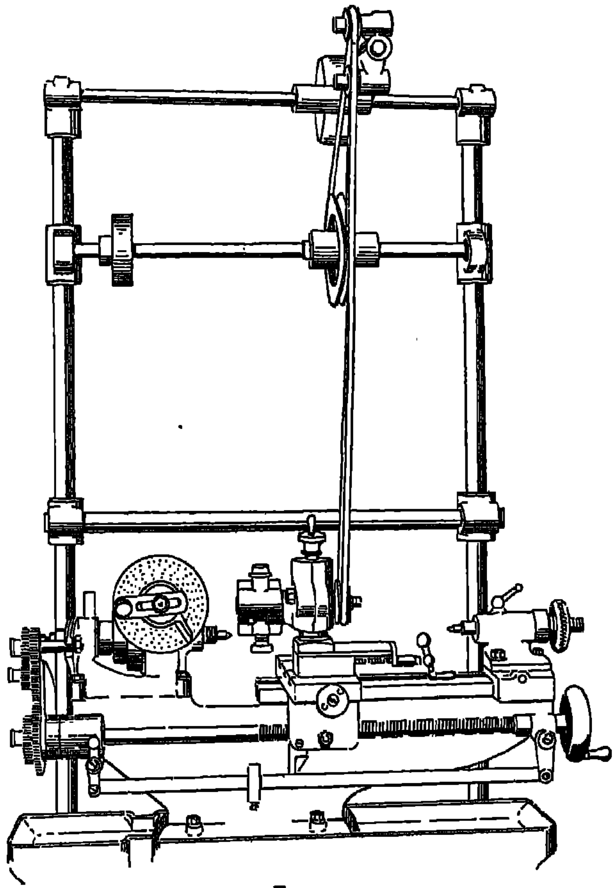


FIG. 13.

With this arrangement both the driving pulley and the tensioning device are kept in line with the milling attachment, and uniform belt tension is maintained.

Driving Bench-Mounted Machine Tools

As in the small workshop the machine tools comprising the lathe, drilling machine and the grinding head are often mounted

on the bench top, a convenient means of driving has to be arranged without unduly encroaching on the limited space available.

Should there be a cross-beam at a convenient height, this will provide a mounting for an electric motor-driven countershaft unit, as is shown in Fig. 14.

This unit, which can be built up on a wooden base, comprises an electric motor, mounted on an adjustable sliding base, driving a countershaft by means of a V-belt.

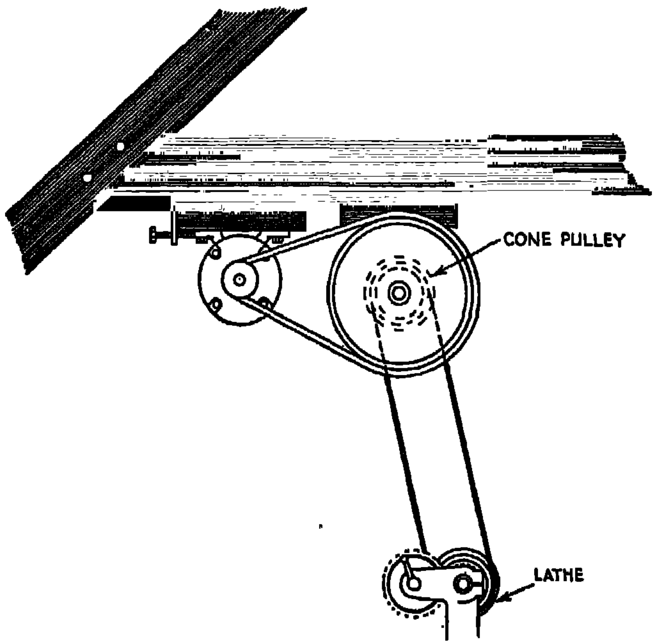


Fig. 14.

The large flat-faced driven pulley is mounted on the countershaft, which runs in self-aligning ball-bearings and carries the step pulley for driving the lathe or drilling machine.

The countershaft, which swings to allow for belt shifting and adjustment, is fitted with a counterpoise in addition to a belt tensioning adjustable stop and a locking lever.

As previously mentioned, an extended form of countershaft of this type may be used to drive a milling attachment mounted on the lathe.

The driving unit, illustrated in Fig. 15, when mounted on the bench is useful for driving small high-speed lathes and

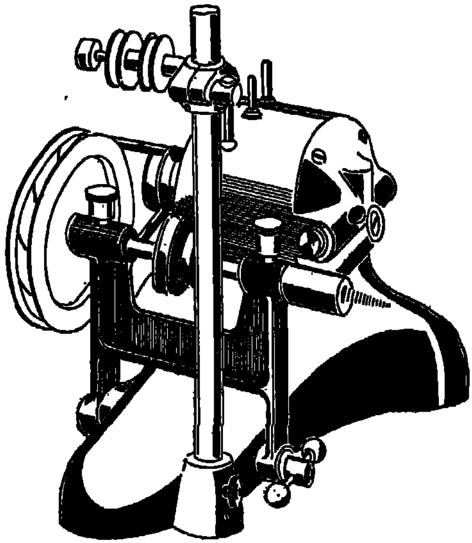


Fig. 15.

their milling attachments, but it has the disadvantages of cumbering the bench top and of being unprotected from swarf.

For driving larger lathes the Myford motor-driven countershaft unit, illustrated in Fig. 16, is designed for mounting on the bench. This device is equipped with an electric motor, mounted on an adjustable base, driving by means of a V-belt a pivoted countershaft fitted with a step pulley to carry the lathe driving belt.

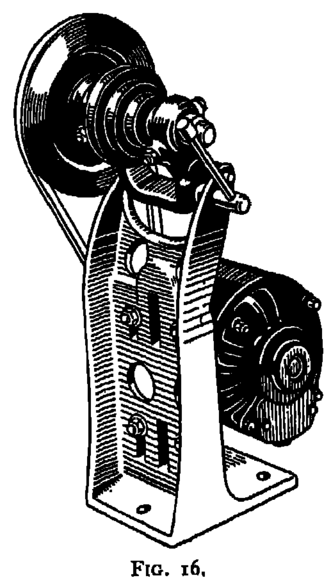


Fig. 16.

As the space on the bench top is usually limited, it is an advantage to drive the machine tools mounted thereon either from above or below whenever possible; in this way, too, the driving units are protected from swarf.

Some lathes are specially designed for use with a driving unit mounted below the bench or accommodated in the lathe

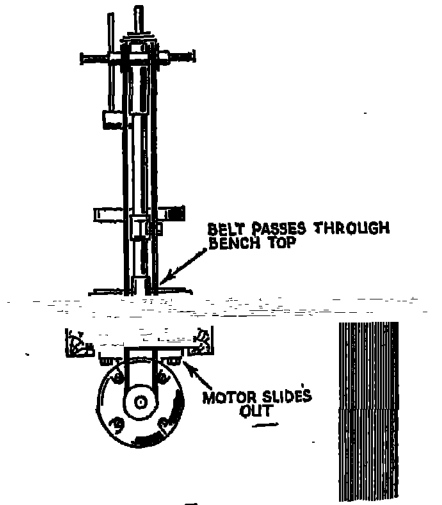


FIG. 17.

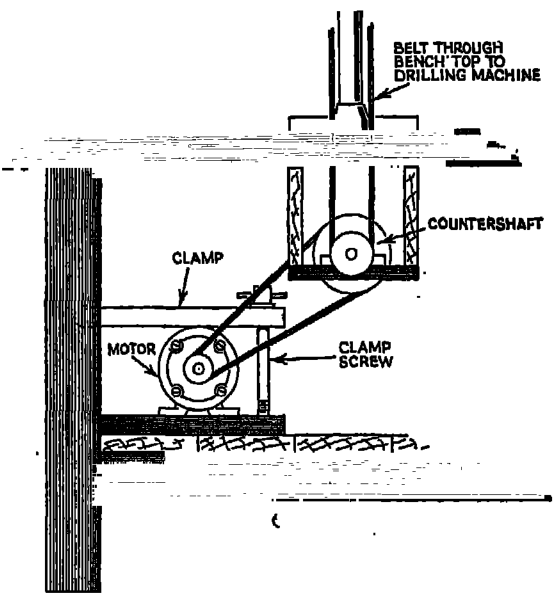


FIG. 18.

stand, but it will be appreciated that this form of drive cannot be employed in the case of lathes of normal design.

Standard types of drilling machines and grinding heads are, however, readily driven from below the bench.

Fig. 17 shows a method of driving a small high-speed drilling machine directly from an electric motor mounted below.

Here, the motor is bolted to a wooden base which engages slides fixed to the underside of the bench top; this allows the motor to be readily withdrawn for inspection and cleaning on the workbench.

In Fig. 18 a countershaft form of drive is shown for use with a larger and slower-running drilling machine.

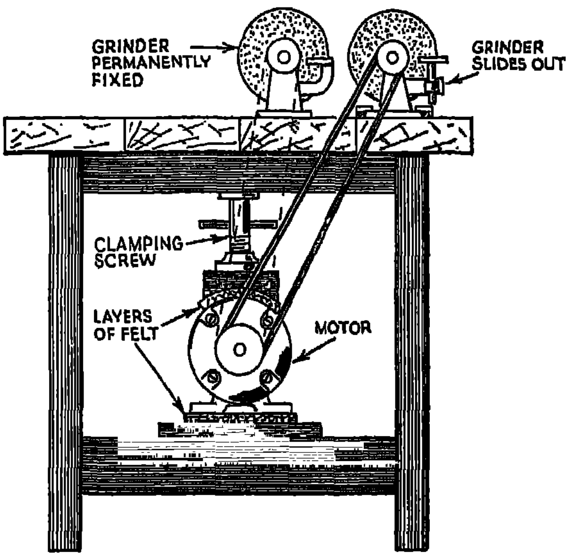


FIG. 19.

In this case, the motor is mounted on a slide for adjusting the belt tension and is secured to its base by means of a screw-operated clamping bar.

This arrangement, too, allows the motor to be quickly removed and replaced when cleaning is required.

In Chapter VIII reference is made to the use of two grinding heads of simple form for rough and fine tool and twist drill grinding. These machines have their driving pulleys positioned outside the shaft bearings in order to facilitate the method of driving illustrated in Fig. 19.

In this case, the base of the grinding head nearer the operator is made to slide out of the way when the use of the further

grinder is required, and, as will be seen, a single motor is used to drive both grinding heads as a measure of economy.

The motor which stands on a pack of felt strips supported by a wooden base, is secured in place by a compression bar formed from a length of conduit tubing.

This tube is screwed into a standard flange-fitting which carries a felt-lined wooden block to press on the motor.

When the tube is unscrewed from the flange the motor will be pressed against its base mounting and so secured in place.

The tension of the belts can be adjusted individually by moving the motor along its base, and both belts can be tightened by further compressing the base mounting or, if necessary, by removing some of the felt strips.

Again, this form of mounting allows of easy removal of the motor, and, in the case of indoor workshops, the liberal use of felt pads will greatly reduce the possibility of noise from electric motors being transmitted to other parts of the building.

CHAPTER V

THE LATHE

General Considerations. The Boley Lathe. The G. A. Lathe. The Mikron Lathe. The Myford Drummond Lathe. The Milnes Lathe. The Myford Lathe. The South Bend Lathe. The Colchester Lathe. Equipment.

General Considerations

Within the space of this chapter it is not possible to describe the operation of the lathe, but guidance on this subject can be readily obtained from the numerous publications dealing with lathe work, which have been compiled as text books or as manufacturers' instructional manuals.

The purpose of the present chapter is, on the other hand, rather to describe the special features to be found in lathes of varying type and manufacture, in order that the would-be buyer can select a tool that will most nearly comply with his ideals and will best meet his special requirements.

It may be that, on the score of expense, a single lathe must serve all workshop needs, and here an adaptable form of machine will be chosen rather than one of the manufacturing type designed primarily for undertaking specialized turning operations; but, on the other hand, where a second lathe is included, the choice may be less difficult and either machine may be better suited individually to deal with the work undertaken.

In the first place, it cannot be gainsaid that the highest quality machine will give the greatest satisfaction, not only in respect of initial accuracy, but also by virtue of its long life and good wearing qualities which will ensure the maintenance of this essential quality.

In this connection, manufacturers will, if requested, usually furnish a copy of the test report of a particular machine showing the limits of accuracy attained, and reference to a table of Schlesinger limits will then give an indication of the quality of the workmanship and of the degree of accuracy that may be expected from the machine when in operation.

Needless to say, quality should not necessarily be judged by the amount of chromium plating expended on accessories, or by the appearance of parts highly finished by the application of emery cloth, but rather by workmanship in general, the working of the machine slides, and the attention paid to useful detail refinements such as the provision of good quality feed-screw indices.

In particular, the free and smooth but shakeless movement of the machine slides is an indication of good workmanship; and, in the case of precision lathes, it may be found that the slides can be moved over a considerable distance by spinning the feed handles with the finger, but, needless to say, the skilled workmanship required to attain this high standard is costly.

Where the initial cost of the lathe is of primary consideration, ultimate satisfaction is perhaps best ensured by buying in the first place a lathe of simple but good fundamental design and workmanship, which can in the course of time be further adapted to the user's needs by the addition of special fittings and accessories; and, moreover, the skilled mechanic can, if he so wish, improve the working of such elements as the machine slides by imparting a hand fit and finish to the already accurately machined components.

In fact, there is but little limitation to the work that the skilled enthusiast can do to improve the working of his lathe, and to enhance the quality of its output.

It must be borne in mind, however, that to expend much time and trouble on a machine of indifferent design or of poor workmanship is largely a waste of effort, and ultimate satisfaction is unlikely to be attained.

Some manufacturers of good quality lathes of simple design supply a large variety of fittings and attachments, by the addition of which their machines can be adapted for special machining operations, such as production and repetition work, or can be otherwise fully equipped to meet all ordinary workshop requirements.

One of the failings most often found of necessity in the cheaper types of lathes is an insufficiency of metal in the bed and headstock castings, for any lack of rigidity in these important parts militates against the maintenance of true alignment when the machine is subjected to the stresses imposed during machining operations.

Futhermore, an ill-designed or weak bed may be deflected when fixed to a wooden bench top, which may itself become distorted by the varying conditions of atmospheric temperature and moisture. When the lathe bed is distorted in this way accurate turning is not possible.

It is essential also that the mandrel itself should be sufficiently rigid, otherwise it will tend to spring when under load; this failing will become apparent under the intermittent loading imposed by milling operations, or when the broad point of a parting tool is presented to the work.

Manufacturers now fully realize the plight of a mechanic who finds that he has acquired a lathe with the tailstock machined out of alignment with the lathe bed or headstock, or that the setting of the cross slide gives inaccurate facing; for these errors are due to faulty manufacture and cannot readily be corrected even by a skilled user.

Nowadays, manufacturing methods ensure that these errors do not occur even in the less expensive lathes, and the more rigid inspection carried out before dispatch is an additional safeguard of the purchaser's interests and the makers' reputation for good workmanship.

Following these introductory remarks, descriptions will be given of some representative types of lathes, most of which are of proved excellence and have given good service for many years past.

Clearly, this account must be confined to a few examples only, and it does not follow that there are not many others, as indeed there are, that are equally worthy of consideration.

Lathes of special design for manufacturing or other purposes do not come within the compass of this chapter, which deals rather with tools suitable for general workshop use, but, at the same time, it must be borne in mind that manufacturers are constantly improving their products and that new designs are frequently produced.

In some instances reference may be made to types which, although no longer manufactured, were of outstanding merit in their time; nevertheless, these lathes may on occasion be offered at second-hand and they are worthy of consideration by the discriminating purchaser. In addition, the manufacture of some of the Continental lathes described is at present in abeyance, but as examples of high-class engineering their reintroduction is fully warranted.

The Boley Lathe

These lathes exhibit a perfection of design and workmanship which undoubtedly places them in the highest class, and apparently but little regard has been paid to the cost of manufacture.

All models are equipped with a true precision type of hardened mandrel running in hardened steel bushes.

The smallest of the series, shown in Fig. 1, is designed for small instrument work and has a centre height of 50 mm. (2 in.). The hollow mandrel is designed for use with draw-in collet chucks, and a large range of accessories is provided to enable diverse machining operations to be performed.

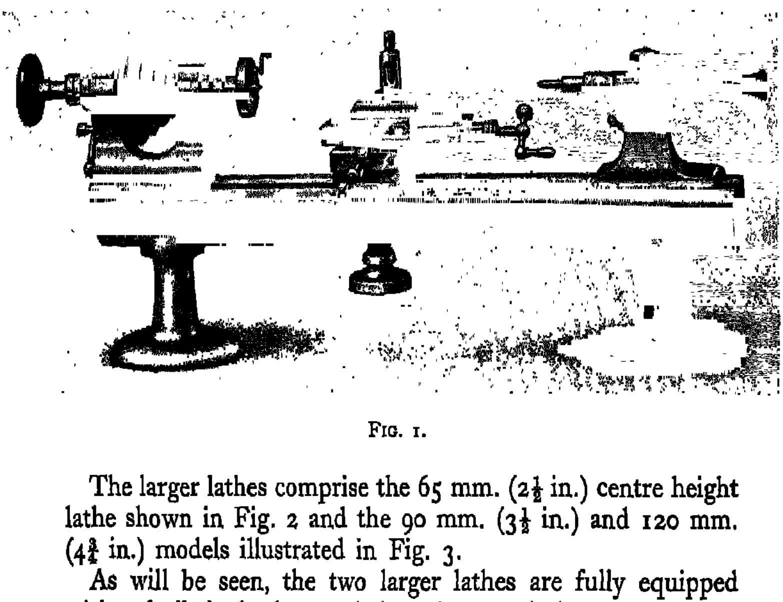


FIG. 1.

The larger lathes comprise the 65 mm. (2½ in.) centre height lathe shown in Fig. 2 and the 90 mm. (3½ in.) and 120 mm. (4¾ in.) models illustrated in Fig. 3.

As will be seen, the two larger lathes are fully equipped with a built-in back gear below the mandrel and the usual screw-cutting mechanism.

In accordance with accepted practice, this precision tool has a bed continuous up to the headstock and with no gap.

The saddle and tailstock have separate guide-ways on the bed, which is fully enclosed and affords protection for the leadscrew lying beneath.

The foot members carry hemi-spherical abutment pieces to avoid the possibility of distortion of the bed occurring when the lathe is bolted to its stand.

The headstock is clamped to the bed by means of two cam-operated clamping devices, and the tailstock is likewise secured by a single quick-action clamp.

The tailstock spindle, which in accordance with the best practice is fully supported throughout its length in the tail-stock body, is actuated by a fine thread central spindle engaging an inset bronze nut member; this affords ample pressure for drilling without causing undue resistance to the feed.

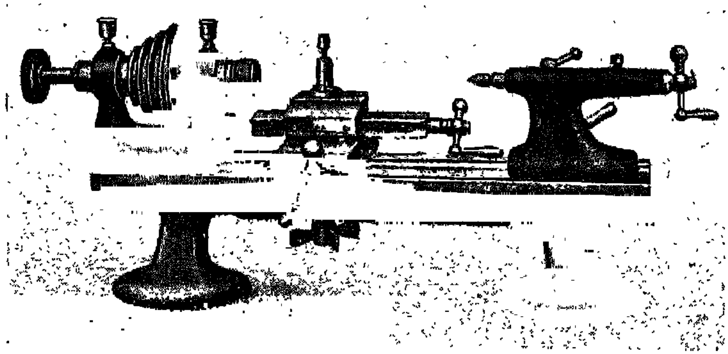


FIG. 2.

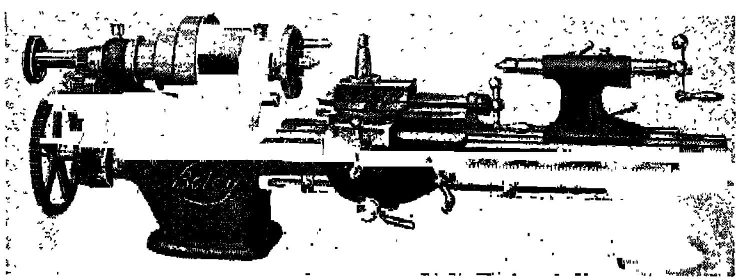


FIG. 3.

The saddle and its slides have that freedom and delicacy of movement which is associated with the most careful and accurate workmanship.

The top slide has the long travel which is a feature of the precision type lathe, and for measurement of feed and to protect the feed screw a graduated steel strip, passing through the nut member, is fitted to the upper surface of the top slide base.

Massive adjustable gib pieces are fitted to the saddle and its slides, and the top slide and the cross slide are provided with large adjustable indices.

An automatic throw-out, operating in either direction, is fitted on the front of the bed to disengage the leadscrew clasp-nut. The reverse gear quadrant is actuated by a friction controlled lever which allows the quadrant gears to traverse the saddle in either direction or to remain idle.

As might be expected, a complete range of accessories has been designed for use with these lathes, and, in addition, special headstocks, tailstocks, saddles and slide-rests have been produced to meet the requirements of manufacturing operations.

As an indication of the quality of these tools, we had a 120 mm. model in use for a period of ten years, and during that time it was not found necessary or desirable to adjust any of the slides or the mandrel bearings; furthermore, if two pieces of work were carefully faced in the lathe they showed a considerable degree of adhesion when wrung together.

The G.A. Lathe

This lathe, produced by the late George Adams but no longer manufactured, was built as a high-class precision tool for the use of instrument makers and for small production work.

The hardened and ground mandrel running in hardened steel bushes was designed for use with standard size draw-in collet chucks. The gapless bed and the machine slides were very accurately finished by hand scraping.

This lathe was made in three models with centre heights of 1½ in., 2½ in. and 3½ in. A wide range of accessories and fittings was obtainable, including gear-cutting attachments and lever operated slides and tailstock.

The Mikron Lathe

This lathe, illustrated in Fig. 4, is a high-class precision tool of Continental manufacture and has a centre height of 90 mm. (3½ in.).

The upper surfaces of the continuous bed are of prismatic form, and flat surfaces machined with T-slots are provided at both the front and rear of the bed for the attachment of accessory appliances.

The hardened and ground mandrel, which is adapted to take draw-in collets, runs in adjustable phosphor-bronze bushes, and a ball thrust bearing is also fitted.

The tailstock of precision lathe type affords support for the graduated spindle throughout its length.

The compound rest is clamped to the bed, and, to allow of screw-cutting, the top slide is actuated by a shaft driven from the quadrant gears, or, alternatively, a thread chasing attachment can be fitted.

The range of work that can be undertaken in this lathe is increased by employing the large number and variety of fittings obtainable, for in addition to the usual accessories there are available a relieving attachment for forming cams, a slotting

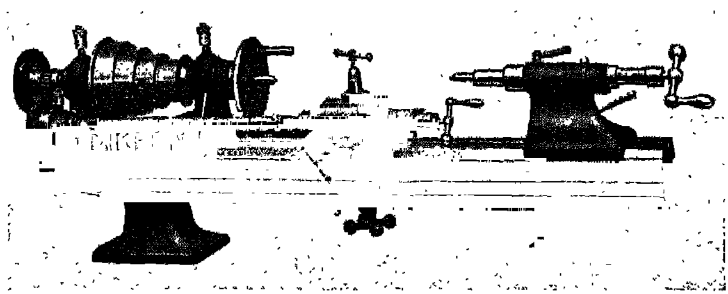


FIG. 4.

attachment, a double slide-rest with lever operation and controlling stops, and a spherical turning attachment.

For manufacturing purposes special types of headstocks are produced fitted with integral chasing attachment, also lever-operated draw-in collets and other essential features.

Tool turrets, with or without a cross slide, are made for fitting to the bed, and the tailstock can also be equipped with a four-station turret operated by a lever feed and controlled by adjustable stops.

The Myford Drummond Lathe

The $3\frac{1}{2}$ in. Drummond lathe was introduced more than forty years ago, and since then, owing to its great adaptability and wide range of usefulness in the amateur and small workshop, it has remained one of the most popular lathes ever made.

Although Messrs. Myford are now manufacturing this lathe, it will be appreciated that the somewhat complex design does not readily lend itself to modern methods of production; nevertheless, the present makers have in some particulars improved the accuracy of the lathe by the adoption of the most modern machining and grinding processes, in conjunction with hand fitting operations wherever necessary.

As this lathe is so widely-known and appreciated there is no need here to describe it fully, but, nevertheless, some of the salient features of its design are well worthy of mention, for they are the outcome of long experience of the requirements of a large body of lathe users.

The cantilever form of bed, with its comparatively small single foot-piece, relieves the bed of any possibility of distortion when the lathe is bolted to the bench top, or to a stand placed on an uneven floor.

As the saddle is guided by the front bed shear only, the mechanical advantage of a long narrow bearing is obtained without the provision of extended lugs to the saddle base.

The mandrel bearings consist of phosphor-bronze tapered and split bushes, which are drawn into their coned seatings by screwed collars to effect concentric adjustment for wear.

The mandrel back gear wheel is locked to and freed from the mandrel by means of a finger-operated stud sliding on an inclined plane.

The change wheels are retained on their studs by split plugs which are readily withdrawn and replaced by the fingers.

The leadscrew is coupled to the quadrant gears by means of a sliding dog-clutch, which is either operated by hand or can be disengaged automatically by a traverse stop.

The large T-slotted boring table affords ample clamping space for the various attachments that are so often used in this situation in the small workshop.

To ensure rigidity, the tool post spigot is formed integrally with the upper top slide member, and carries a box-form tool post which is readily adjustable for height and angularity. This method of construction relieves the top slide of any stress that might cause deformation when the tool is clamped.

In the original design, as the saddle was traversed solely by the leadscrew in the absence of a rack gear, an operating handle was of necessity fitted to the end of the leadscrew; this valuable feature has been retained in all subsequent models.

The tailstock spindle is parallel throughout and thus obtains guidance from the tailstock body over its entire length. The tailstock is clamped to the lathe bed by a cam-action device, which ensures that the tailstock base engages the alignment face on the front bed shear which also guides the saddle.

During manufacture, the whole surface of the bed is ground in the surface grinding machine, and the guide-ways of the

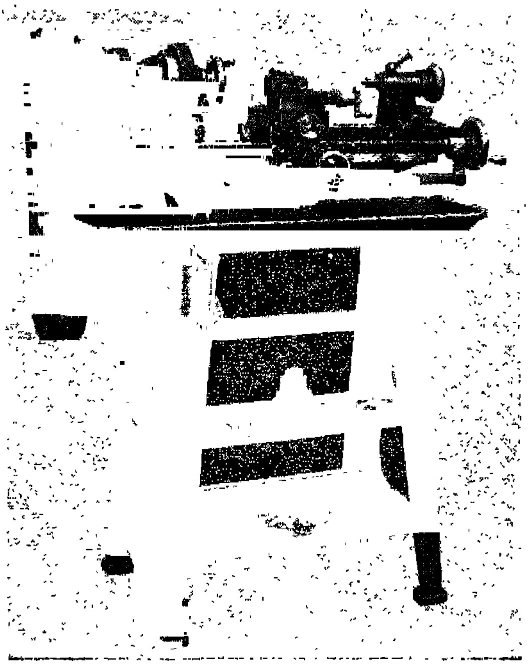


FIG. 5.

bed and the corresponding surfaces of the saddle and tailstock are accurately finished by hand scraping.

The exacting final test inspection of the lathe ensures that a high degree of accuracy is maintained in all essential particulars.

The illustration, Fig. 5, shows the lathe on a stand mounting and equipped with self-contained electric motor drive controlled by a forward and reverse switch.

As an alternative, a bench motor-countershaft unit is supplied for driving the bench model lathe.

The Milnes Lathe

This lathe of $3\frac{5}{8}$ in. and $3\frac{3}{4}$ in. centre height, although not now manufactured, was a high-class machine tool of simple but robust design combined with good workmanship.

Its adaptability was comparable with that of the Drummond lathe and rendered it eminently suitable for installation in the small workshop.

In addition to this model, a lathe of 5 in. centre height was formerly manufactured, but here the design was more elaborate, and a separate feed shaft for actuating the saddle traverse was fitted, and a feed shaft at the back of the bed furnished a power drive for the cross slide feed mechanism.

The Myford Lathe

Messrs. Myford now make a $3\frac{1}{2}$ in. centre lathe, the ML 7, of advanced design, which is produced in accordance with the most modern machining methods for the maintenance of accuracy during manufacture.

In addition, advantage is taken of the use of special materials for components and fittings to give the best results and avoid unnecessary cost.

As will be seen in the illustration in Fig. 6, the lathe can be used either on the bench or fitted to the makers' specially designed stand, which is fabricated from sheet steel and carries the forward and reverse switch.

The electric motor drive with its swinging countershaft is attached to the lathe itself, and a sliding cover is fitted to guard the V-belt drive and to facilitate shifting the belt for change of mandrel speed.

The robust gap bed is designed to afford long narrow guidance for the saddle from the front shear only; a feature which greatly helps to maintain the accuracy of the saddle movement, and obviates the necessity of unduly lengthening the saddle guideways.

The headstock is offset from the centre line of the bed to provide greater rigidity when turning large diameter work, and the enclosed back gear is fitted below the mandrel.

The high tensile steel ground mandrel, which is bored $\frac{19}{32}$ in., runs in anti-friction alloy bushes adjustable for wear by means of laminated shim material.

To maintain accuracy and minimize wear, the saddle has a bearing area of no less than 19 sq. in. and is provided with

felt pads to lubricate and to exclude swarf from the sliding surfaces.

The apron is provided with the usual rack and pinion quick traverse gear, and carries a hand lever for operating the leadscrew nut; in addition, a thread index is fitted at the rear end of the saddle.

The cross slide, which has an area of 30 sq. in. and a travel of 5 in., forms a useful boring table and has four ⅜ in. T-slots machined in its upper surface.

The top slide is readily adjustable for angularity and, if required, will accommodate the makers' four-tool turret.

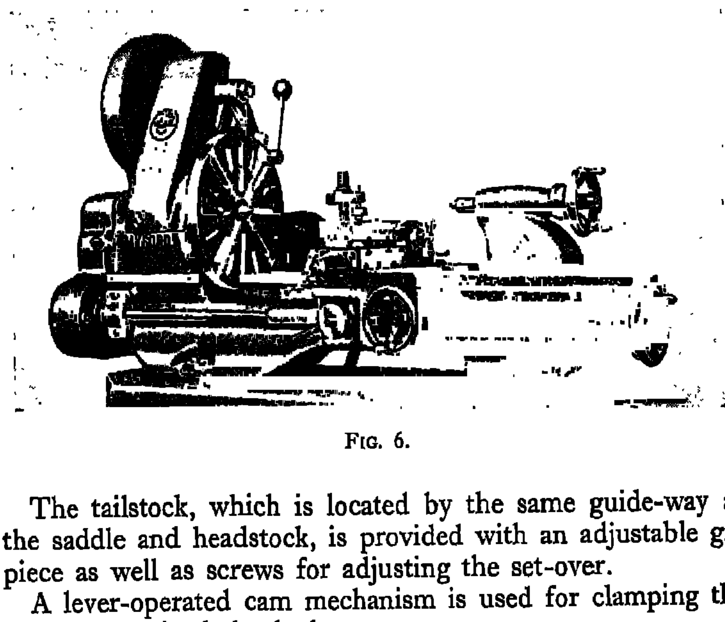


FIG. 6.

The tailstock, which is located by the same guide-way as the saddle and headstock, is provided with an adjustable gib piece as well as screws for adjusting the set-over.

A lever-operated cam mechanism is used for clamping the tailstock to the lathe bed.

The leadscrew hand-wheel with its large graduated index is a fitting which many users of a lathe of this type regard as essential; this component can be fitted, if required, at a small extra cost.

The lubrication arrangements are very thoroughly carried out by the provision of Oilite bushes and Bennet type lubricators at all important points.

As previously mentioned, a four-tool turret can be attached to the top slide. This fitting is provided with a ratchet gear

which indexes the tool setting to eight stations, and the device is so designed that swarf is prevented from interfering with the correct location of the turret and the position of the tool.

In addition to the usual accessories, attachments for taper turning, gear cutting, and slotting are available.

The South Bend Lathe

This lathe is made in sizes of from $4\frac{1}{2}$ in. to 8 in. centre height, and of these the $4\frac{1}{2}$ in. or Workshop Model is perhaps the best known and the most widely-used by reason of its adaptability and general utility in the small workshop.

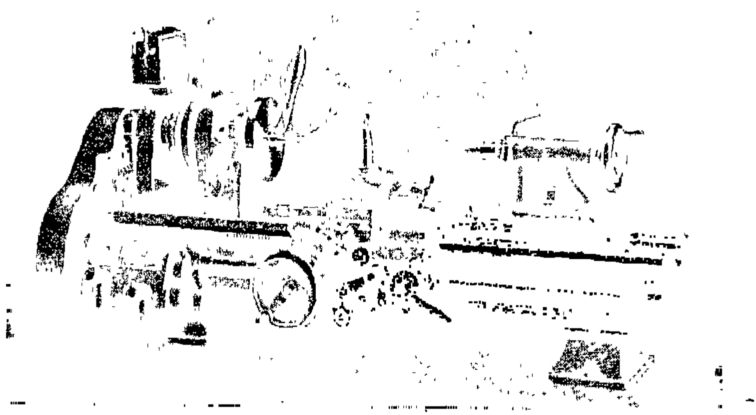


FIG. 7.

As will be seen in the illustration in Fig. 7, this lathe has a continuous bed with inverted V-guides and no gap, for the makers point out that, by using the raising blocks which they supply, the capacity of the lathe is increased over the whole length of the bed and not merely in the gap; and, in addition, the advantages of the continuous bed when working close to the headstock are retained.

The headstock is fitted with a back gear engaged by finger operation, and the ground mandrel, which is bored $\frac{1}{2}$ in., runs in adjustable integral cast-iron bearings.

The cross slide and the top slide feed screws are fitted with adjustable indices, and the tailstock spindle is graduated.

The Workshop Model is made in three types: Model A is equipped with a quick-change gear box and an apron gear which affords both automatic traverse and surfacing feeds; Model B has plain quadrant gear change equipment, but a similar apron gear is fitted; Model C has a quadrant gear change and an apron which affords automatic traversing only.

Several methods of driving these lathes have been devised by the makers; when mounted on a stand the drive may be by means of an electric motor-countershaft unit attached to the back of the lathe; the lathe may be driven by a similar unit attached to the under side of the bench top on which the lathe is mounted; or this type of driving unit may be secured to the bench top at the rear of the lathe as shown in the illustration.

For driving the countershaft a V-belt is used, but the drive from the countershaft to the mandrel may be by either a flat or a V-belt. In the latter case a four-step pulley is used to provide eight spindle speeds.

Of the larger South Bend lathes the 5 in. Tool Room model is noteworthy by reason of its elaborate equipment, and its large collet capacity of 1 in. in conjunction with the $1\frac{3}{8}$ in. bore hollow mandrel.

The range of accessories supplied by the makers for all models of their lathes is very complete, and, to name only a few, includes grinding attachments, a bed turret, a milling attachment, micrometer carriage stops, draw-in collet chuck equipment, and a taper turning attachment.

The Colchester Lathe

This series of lathes of robust construction and straightforward design, is eminently suitable for general use in the workshop where a high-class machine tool is required.

The smallest of the series, the Bantam, illustrated in Fig. 8, has a centre height of 5 in. and is supplied with a stand for treadle or countershaft drive, or, alternatively, the stand can be equipped with a self-contained electric motor drive.

The gap bed is of heavy section well braced with cross webs, and the inverted V guide-ways and sliding surfaces are accurately ground.

The headstock houses the back gear mechanism below the mandrel to afford greater rigidity, and protection of the gears.

The hollow mandrel is bored $\frac{3}{4}$ in. and runs in adjustable

phosphor-bronze bearings of ample proportions; in addition, a ball-bearing is fitted to take thrust loads.

The apron and saddle are of heavy construction, and a thread indicator is fitted to facilitate screw cutting.

The cross slide feed screw is equipped with an adjustable index, and the top slide carries a box-form tool post which allows of adjustment of the tool height.

The next larger lathe in the series is the Master, with a centre height of 6 in. and a hollow mandrel of 1¼ in. bore.

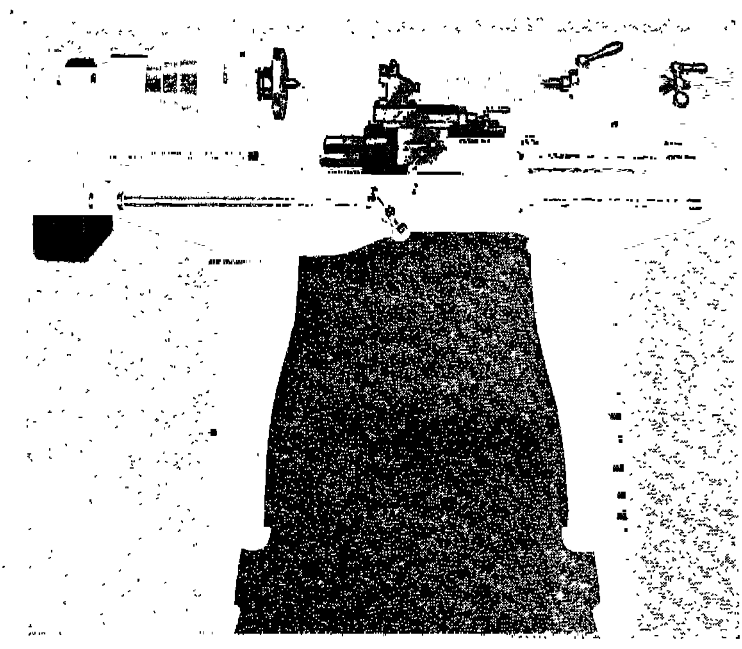


FIG. 8.

This lathe is well suited for dealing with the heavier machining work in the general workshop.

The automatic sliding and surfacing motions are both controlled from the apron by a single handle, and a two-speed gear box is fitted to the feed shaft.

If desired, taper turning and draw-in collet attachments can be supplied with the lathe at the time of manufacture.

In addition, this lathe can also be obtained with an all-geared head, or with the all-geared head and a self-contained electric

motor drive; when so equipped the lathe has eight spindle speeds ranging from 20 to 550 revolutions per minute.

The drive of the all-geared head is controlled by a clutch and hand lever, and a reverse gear both for the feeds and for screw cutting is incorporated in the headstock.

The larger lathes manufactured by this Firm are the 6½ in. and 7 in. centre Triumph, and the 8½ in. centre Mascot; both these models can be supplied with a quick change gear box which, without change of wheels, will cut screw threads of from 4 to 56 threads per inch, and will give feeds of from 12 to 168 per inch.

Equipment

In general, advice as to the equipment of lathes with accessories and fittings is best obtained from the manufacturers, for they will, by reason of their special experience, know what is most suitable for use with their products.

Moreover, lathe manufacturers usually specify in their catalogues and instruction books not only the most suitable proprietary articles, such as chucks and lathe tools, but also the special attachments which they have produced for use with their machines.

When extra equipment, such as a draw-in collet chuck attachment, a taper turning attachment, or a boring table to replace the standard cross slide is required, the manufacturers should be informed when the lathe is ordered, as, to ensure satisfaction, these accessories have usually to be fitted to the lathe at the time of manufacture.

CHAPTER VI

THE DRILLING MACHINE

Types of Drilling Machines. Drill Speeds. Machining Drilling Machine Components. Modifications of Design. Testing the Drilling Machine. Drilling Machine Fittings. Chucks. Drilling Operations. Cross-Drilling Shafts. Countersinking, Counterboring and Spot-Facing. Tapping. Lapping and Polishing. Milling.

IN commercial engineering, when drilling on a large scale is undertaken, the work may be allotted to drilling machines of suitable capacity and speed range to ensure maximum output, and if necessary special machines are installed for any particular purpose.

In the small shop, on the other hand, this machining is carried out with the tools available, which may in many cases comprise only a small high-speed drill and a larger machine for heavier work.

As the work demanded of these machines will cover a wide range, it is essential that their speed should be variable accordingly, and that they are capable of accommodating unusual work, or even performing machining operations normally carried out on machines of special types.

For example, a high-speed machine with sensitive feed will be required for boring carburetter jets with a No. 75 drill, whereas for heavy counterboring and countersinking a rigid slow-speed machine is called for.

Types of Drilling Machines

As an example of a well-designed but simple type of high-speed sensitive drill of ¼ in. capacity, the machine described in the *Model Engineer* in 1941 may be cited. Although the model of this machine with self-contained countershaft is shown in Fig. 1, as an alternative a plain base casting is available for those who prefer direct electric motor drive.

This machine is so designed that the machining operations necessary for its construction can be carried out in a 3½ in.

gap bed lathe, and, moreover, the castings, materials and blueprints can be obtained from Mr. Haselgrove, whose address will be found in the section at the end of this book.

The simplicity of the machine makes for easy construction, and, by methodical machining, a tool of high accuracy and great utility can be built.

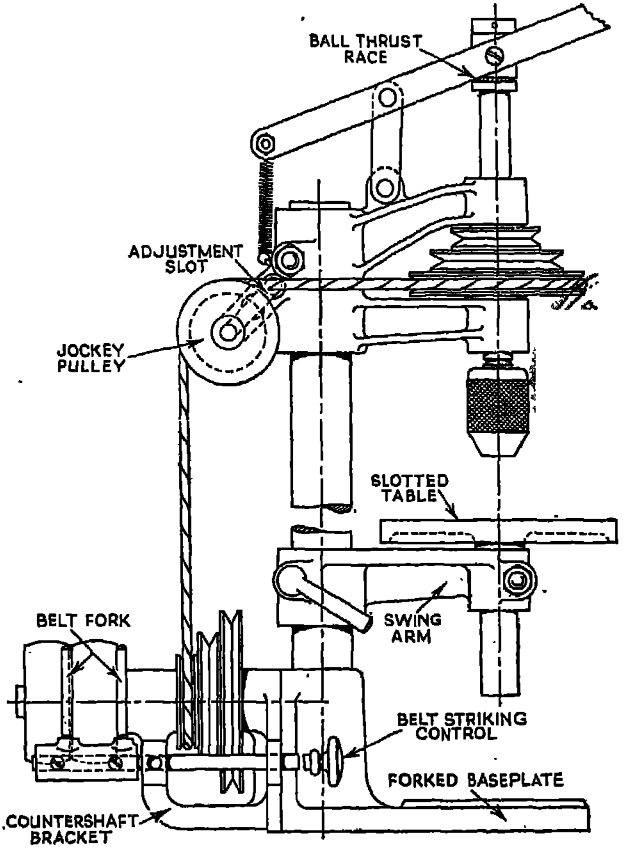


FIG. 1.

It will be seen that a spindle, sliding and rotating in its bearings, is used, and, although exception might be taken to this design in a machine intended for manufacturing purposes, it has been found that this form of construction has not in practice proved a disadvantage in the small shop, provided that in the first place the bearings are accurately fitted, and the machine is kept clean and regularly lubricated.

Later in this chapter, some of the more important constructional machining operations will be described in detail, as well as some additions and modifications that have been found to enhance the utility of the machine.

Fig. 2 illustrates a $\frac{1}{2}$ in. capacity sensitive drilling machine, marketed by Messrs Buck & Ryan, which is of more elaborate design. Here, the spindle revolves in a quill which is actuated by a rack and pinion feed gear, thus eliminating sliding movement of the spindle in its bearings and increasing the leverage available for drilling.

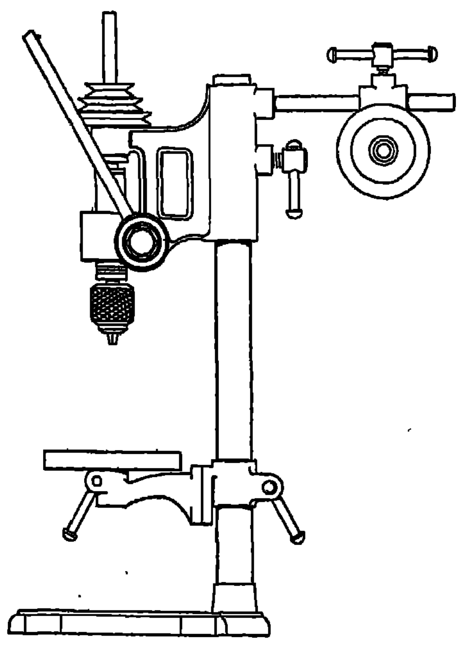


FIG. 2.

The specification is further elaborated by the provision of a tilting table, a depth stop, a feed scale and an enclosed return spring for raising the spindle.

A $\frac{3}{8}$ in. capacity drilling machine of similar type, but fitted with bevel gear drive to the spindle, is illustrated in Fig. 3. In the past, Messrs. Tom Senior and other firms have supplied castings and machined parts for building these machines.

The constructional work is quite straightforward, and the completed machine, if carefully made, will give long and

accurate service; in fact, an example built more than twenty-five years ago is still in use and has well maintained its accuracy.

As will be seen, the machine is fitted with a rack and pinion operated quill, which slides in an adjustable split housing; the spindle carries a $\frac{3}{8}$ in. Jacob drill chuck and is provided with a ball thrust.

In the machine under discussion, the horizontal driving shaft is fitted with split clamp collars, to allow of accurate

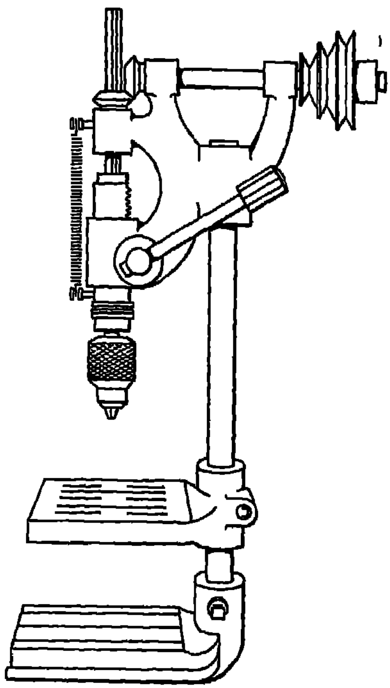


FIG. 3.

adjustment of the meshing of the bevel pinions; in addition, an adjustable depth stop is fitted to the upper end of the spindle, and a scale is attached to the quill housing to measure the depth of drilling.

For heavier drilling and for operations such as counterboring, it is advisable to employ a machine of robust construction, such as that illustrated in Fig. 4.

This machine is of $\frac{1}{2}$ in. capacity, and the distance of the spindle centre to the column is 6 inches.

As will be seen in the drawing, a depth stop is fitted and the spindle, running in a quill actuated by a lever feed, is equipped with a ball thrust and a ½ in. capacity drill chuck.

The machine illustrated is driven by a self-contained slow speed electric motor of ⅓ h.p., but a similar model for countershaft drive is obtainable.

When a machine of this type is required for general work, it is essential to ensure that sufficiently low spindle speeds are available, and to this end it may be necessary to provide an intermediate reduction gear, as will be described later, or to fit an epicyclic geared pulley to the machine spindle.

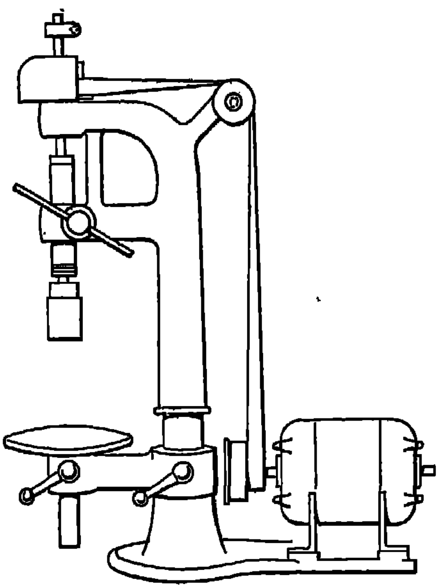


FIG. 4.

The small portable electric drill has many uses in the workshop, and, moreover, when mounted on a stand furnished with a lever feed mechanism and an adjustable depth stop, it forms a useful high-speed sensitive bench drilling machine, although the spindle speed is constant, except for the reduction entailed by the increased loading when larger drills are used.

Fig. 5 shows the ¼ in. capacity Wolf electric drill mounted on the makers' bench drill stand. When running light the spindle speed is approximately 2,800 r.p.m., but under full load this is reduced to 1,400 r.p.m.

The type of ½ in. capacity drilling machine, with self-contained drive, illustrated in Fig. 6, is now justly popular by reason of its great speed range, robust construction, and the superior design of the spindle and its bearings.

The actual machine illustrated is the Grafton, which is British made and is distributed by Messrs. Buck & Hickman.

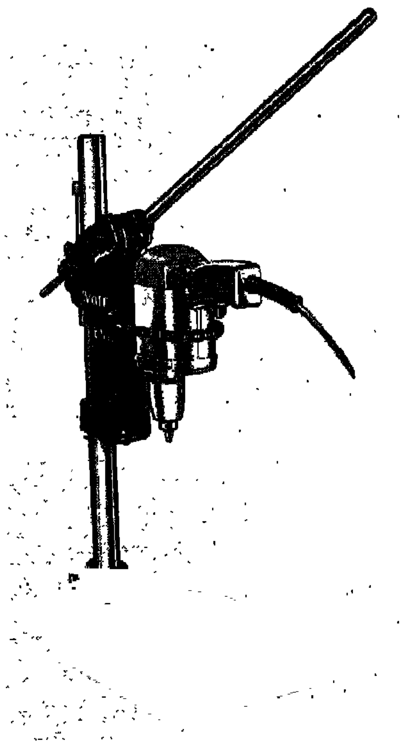


FIG. 5.—Wolf Electric Drill.

As will be seen, the spindle is driven by an endless V-belt from a ⅓ h.p. electric motor, mounted on the column with provision for belt tensioning.

In addition, as shown in Fig. 7, a layshaft and pulley, termed the Hi-lo speed attachment, can be fitted to the column to give a wider speed range.

The standard speeds without this attachment are 575,

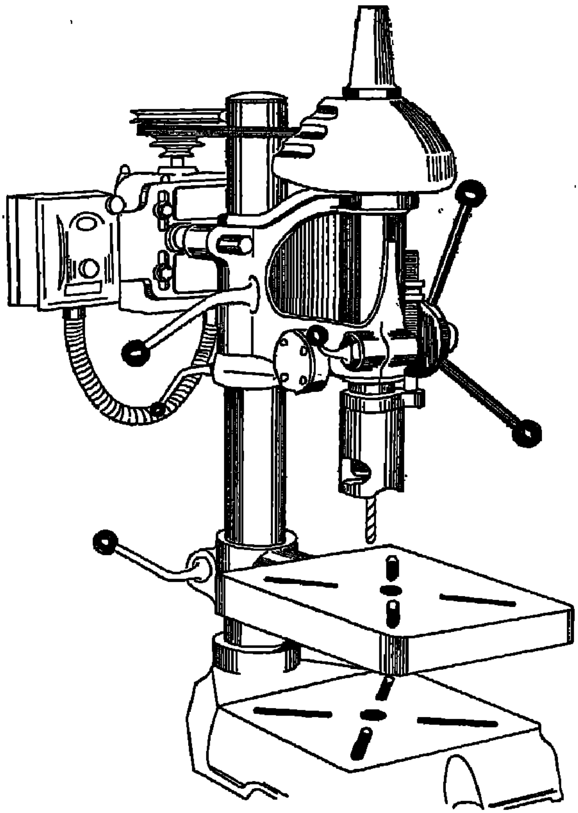


FIG. 6.

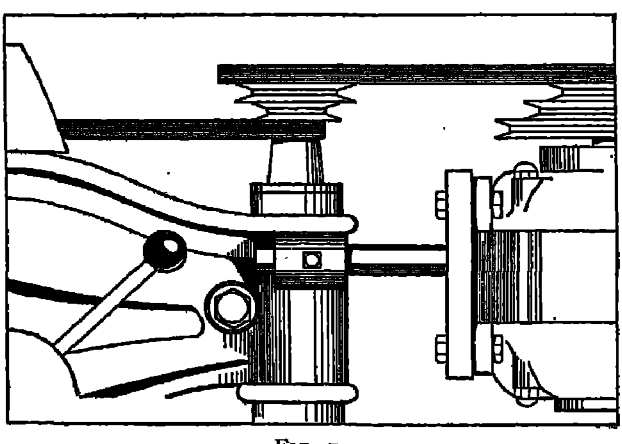


FIG. 7.

1,070, 2,050, and 3,820 r.p.m., but with the Hi-lo in use the speeds obtainable range from 200 to 8,000 r.p.m.

Fig. 8 illustrates the detailed construction of the spindle head and its bearings, which are designed to ensure rigidity and long service, together with free running even at the highest spindle speeds.

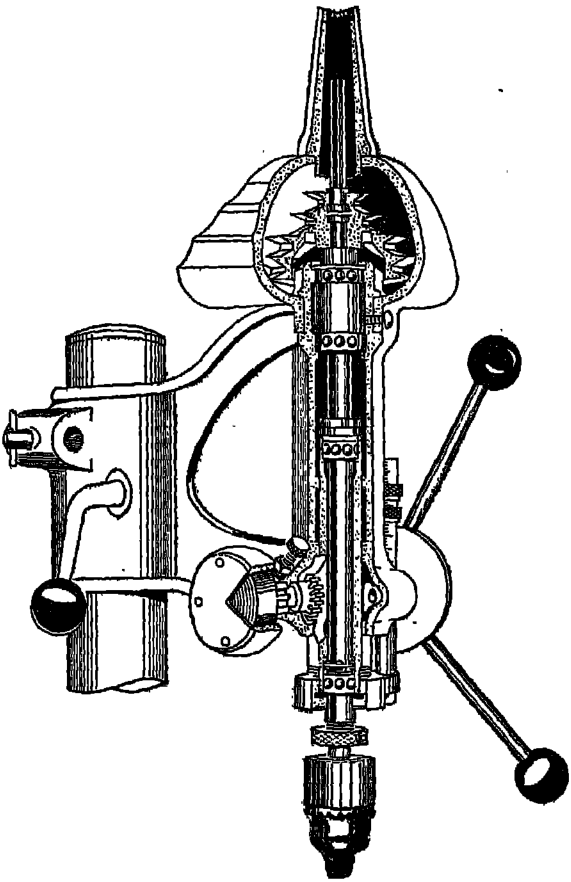


FIG. 8.

Although not primarily designed for use as a drilling machine, the small precision high-speed vertical milling machine described in Chapter VII is eminently suitable for drilling operations where accuracy and high spindle speeds are essential.

In addition, the collet chucks with which the machine is equipped ensure that the drills are accurately held.

Drill Speeds

Twist drill manufacturers recommend that for satisfactory and accurate drilling the correct speeds for their drills should be used.

In general, for carbon steel drills used on mild steel and cast-iron a peripheral speed of thirty feet per minute is suitable, and this may be increased to sixty feet per minute in the case of brass and aluminium alloys.

When high-speed steel drills are used these figures may be doubled.

It is essential when drilling cast iron that free cutting should be maintained, for any tendency to rub, particularly in the case of large drills, will rapidly cause blunting of the cutting edges and wear of the lands at the point. As this reduction in diameter causes undue friction and a tendency for the drill to jamb in the work, it may be found advisable to reduce the speed of rotation when drilling cast iron.

TABLE OF CARBON STEEL TWIST DRILL SPEEDS

(Morse Company)

Drill Dia. in.	Revs per Min.	Drill Dia. in.	Revs. per Min.
$\frac{1}{16}$	1,833	$\frac{1}{2}$	214
$\frac{1}{8}$	917	$\frac{9}{16}$	176
$\frac{3}{16}$	611	$\frac{5}{8}$	159
$\frac{1}{4}$	458	$\frac{3}{4}$	132
$\frac{5}{16}$	342	$\frac{7}{8}$	105
$\frac{3}{8}$	285	1	90
$\frac{7}{16}$	244		

These speeds are for steel and may be doubled for drilling brass.

For high-speed-steel drills all speeds may be doubled.

Machining Drilling Machine Components

When building a drilling machine from castings most of the constructional work is quite straightforward, but as the accurate alignment and fitting of the spindle bearings is essential for satisfactory working and may cause difficulty to some, it will not perhaps be out of place here to describe the machining operations involved.

In the first place, the drill head is bored in the usual way, and is then clamped to the ground column on which it will

be mounted in the completed machine. If this column is truly lined up and fixed to the lathe saddle, the spindle bearings can then be bored with an accuracy equal to that of which the lathe is capable.

As shown in Fig. 9, a bracket is clamped to the column for attachment to an angle plate bolted to the lathe boring table. In this instance the table of another drilling machine was so used, but if this is not available, the column may be clamped in place on V-blocks, or in a Keats V-angle plate bolted to the lathe saddle.

If, as shown, the tail of the column is allowed to project backwards for some twelve inches, this portion may be used

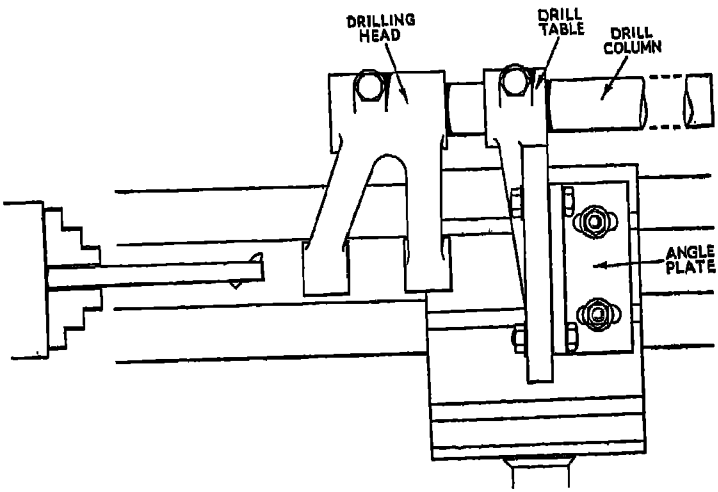


FIG. 9.

for setting the column, by means of a dial test indicator, both vertically and horizontally parallel with the lathe bed.

When the centre of the spindle bearings has been set to the line of the lathe axis, by rotating the drill head on its column and adjusting the cross slide, the drilling and boring of the bearings is proceeded with, but leaving the bore some two-thousandths of an inch under-size for reaming.

After reaming, and while the drill head is still clamped to the boring table, the spindle bearings are lapped to secure final accuracy. To avoid the possibility of side thrust, the lap should be flexibly mounted when driven from the chuck. A short length of stout rubber tube or a piece of coil spring

makes a convenient and serviceable flexible coupling when attached to the driving member.

If the coil spring fits closely and is wound in the right direction, it will be self-tightening under load and will carry the drive without further fixing.

The lapping process is continued until the bearings are truly parallel on gauge measurement, and all tool marks have been eliminated.

A tapered hardened and ground mandrel makes a satisfactory gauge for this purpose, and a good view of the bearing surfaces may be obtained by using a dental mirror in conjunction with a flash lamp.

The set-up for machining the spindle bearings should also be used, before dissembling, for boring the drilling machine table bracket.

The spindle is turned a little oversize and is then lapped to fit its bearings, for upon the accurate fitting and finish of these parts will depend the satisfactory working and useful life of the completed machine.

In the Model Engineer drilling machine, and in other drills of this type, a key fixed in the driving pulley engages a keyway cut in the spindle to transmit the drive, and, to ensure and maintain smooth working, the machining of these parts should be accurately carried out.

The thickness of the steel selected for the key should in the first place be measured with a micrometer, and a square-ended tool bit is ground and stoned to this dimension.

This tool is then mounted at right angles in a small boring bar held in the chuck, and the drill spindle is clamped to the lathe saddle at the correct height to cut the requisite depth, that is to say the full depth of the keyway. With the cross slide adjusting screws tightened somewhat to prevent snatching, the spindle is fed to the fly cutter, and the keyway is cut to its full depth at a single operation.

The use of the automatic cross feed gear facilitates the machining, which, although it takes some time to complete, ensures a better finish to the work than the alternative method of end-milling.

The breadth of the tool is now reduced by one-thousandth of an inch on an oil stone, and the tool bit, when clamped in the boring bar, is used to cut the keyway in the pulley by a shaping operation carried out in the lathe.

For this purpose, the pulley is held in the chuck and the boring bar is fixed in the lathe tool post; the keyway is then machined by traversing the saddle or top slide to and fro, while the tool is fed radially outwards at the lathe centre height.

On completion of the machining, the key should be a firm press fit in the pulley and a smooth sliding fit in the spindle keyway.

Modifications of Design

During the construction of this drilling machine some modifications of the original design were made, with a view to effecting minor improvements and satisfying personal requirements.

A standard $\frac{3}{8}$ in. ball thrust bearing was fitted at the upper end of the spindle, and the thrust block, illustrated in Fig. 10, was made of cast iron to afford a better bearing.

This thrust member (A) is located and adjusted by means of a split clamp collar (B), embracing the upper end of the drill spindle. An axial oilway, with a radial opening into the thrust block bearing, is drilled in the upper end of the spindle, and this oilway is closed by a hexagon-headed screw (C), which is also used to press the lower fixed thrust race into position during assembly.

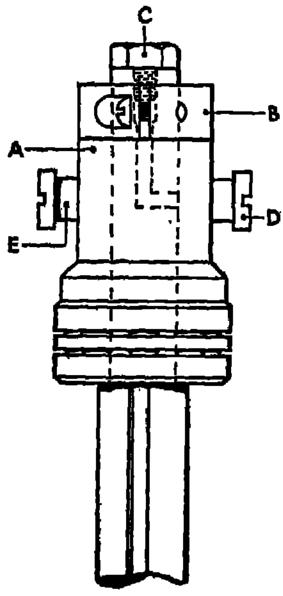


FIG. 10.

The trunion screws (D) carry cycle chain roller bushes (E), which in turn engage cycle chain rollers pressed into the side members of the operating lever assembly.

In the same manner, the swing links and their upper fulcrum screws are bushed with hardened chain rollers and bushes to minimize wear, and to afford easy replacement if required.

As illustrated in Fig. 11, the jockey pulley spindle is carried in a swinging bracket, clamped to the lug on the head casting by a cross bolt and thumb lever.

This method of construction gives a wide range of both vertical and horizontal movement to the jockey pulleys, and

allows adequate belt adjustment when using various sizes of driving pulleys.

Both the bores of the jockey pulleys and their shafts were lapped to size in order to ensure quiet running and long bearing life.

The drill chuck is held to its taper on the spindle by a 4 B.A. countersunk screw, which passes through a hole, tapped 2 B.A., in the chuck base. A 2 B.A. screw can therefore be used to press the chuck from its taper, and a 4 B.A. screw,

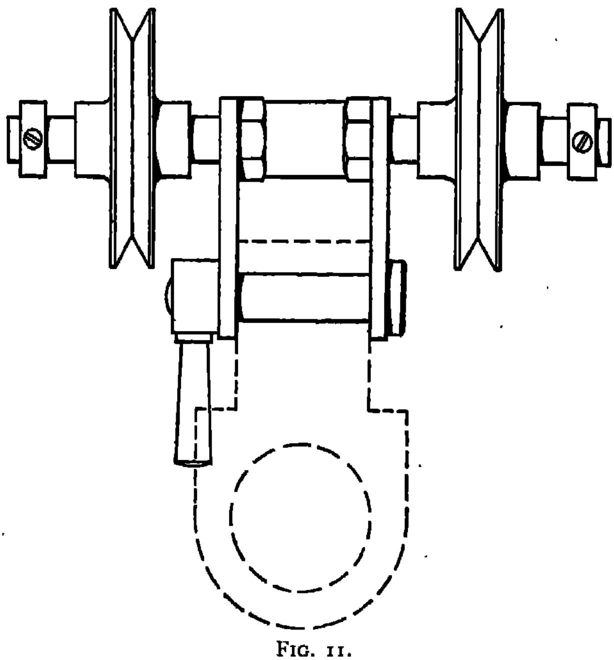


FIG. 11.

inserted into the lower end of the spindle, may be employed with a suitable distance piece to withdraw the drill spindle from the fixed thrust race at its upper end.

The drill spindle and its components can thus be assembled and dissembled entirely by integral screw pressure, so dispensing with the use of the hammer for this purpose.

Testing the Drilling Machine

When the machining has been completed, the drilling machine should be tested for accuracy of alignment, although this should not be at fault if the work has been done methodically.

For this purpose, the column is supported on V-blocks on the surface plate, with the drill head and spindle lying horizontally. Readings are then taken with the dial test indicator to make sure that the column lies truly parallel with the surface of the plate.

When this has been checked, and if necessary adjusted, further readings are taken at the ends of the parallel portion of the spindle and any errors of alignment are noted. The column is then rotated to bring the spindle uppermost and readings are again taken.

Consideration of these measurements will reveal any lack of parallelism between the spindle and the drill column.

When the column is still on the surface plate, the accuracy of alignment of the drill table can also be tested in two planes by applying an accurate square.

The relative accuracy of alignment of the components in the assembled machine can also be checked by means of a test indicator, mounted on the lower end of the drill spindle, and rotated by hand whilst making contact with the machine table.

Needless to say in any machine of good quality the errors detected in this way will be exceedingly small.

The true holding of the chuck should also be verified, by engaging the test indicator with a short length of straight rod, held in the chuck and slowly rotated.

At the same time, the fit of the bearings and the lateral rigidity of the machine can be tested by rocking this rod with the finger and noting any deflection shown by the test indicator. To test the vertical rigidity of the machine, attach the test indicator to the head casting, with its contact point engaging the drill table, and apply pressure to the table with a drill by means of the feed lever as when drilling; any spring due to lack of vertical rigidity will at once be apparent.

Drilling Machine Fittings

Whenever possible, a depth stop and a drilling scale should be fitted, as these greatly facilitate many drilling operations.

When repetition drilling is undertaken, and both hands are engaged, a foot switch or foot-operated clutch, fitted to the driving gear, will be found a great convenience.

An accurate machine vice of a size suitable for the drill table is essential, and, moreover, it should be provided with wing-screws for clamping in place from the underside of the table.

An adjustable clamp collar to maintain the height of the drill table, when swung sideways, is at times a most useful fitting when accurate depth drilling is undertaken.

A device for this purpose and suitable for the Model Engineer drilling machine is shown in Fig. 12.

Chucks

Good quality chucks are strongly recommended, for not only do they hold truly and firmly without damaging the drills, but also they have a long working life if carefully treated and not over-stressed.

In small drilling machines the chuck is usually fitted directly to the spindle to minimize overhang and maintain true running,

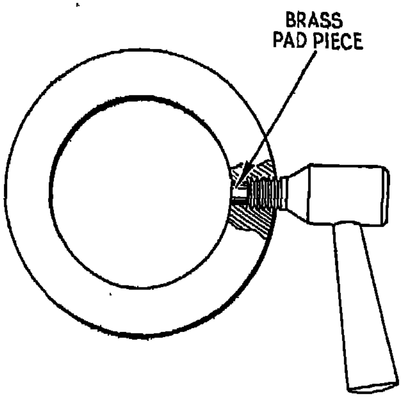


FIG. 12.

but the larger machines may have a spindle nose bored to take tools with Morse taper shanks, such as counterbores and tapping attachments, in addition to twist drills.

Drilling Operations

To ensure the accurate location of drilled holes, certain fundamental principles should be rigidly observed. The centres of the required holes are usually determined by the intersection of two marking-out lines scribed at right angles. With the aid of a magnifying glass the point of a small sharp centre punch is placed at the intersection point, and a light hammer blow is administered to the punch when held truly vertical to the surface of the work. The work is examined with the magnifying glass, and any error of position is corrected

by drawing over the hole with the punch slightly inclined to the work; the punching is then continued until the punch-mark is seen to be accurately placed and of sufficient depth to locate the drill point.

Experiment has shown that by the use of this method accuracy to within three-thousandths of an inch should be attained.

A short stiff Slocomb centre drill is then used in the drilling machine to enlarge and deepen the punch-mark, and the diameter of the drilled centre hole should not be less than that of the drill which follows.

Except in the case of small drills, a pilot drill should precede the larger drill in order to maintain accuracy and to ensure easier cutting.

It saves time to keep accurately sharpened high-speed drills of say $\frac{1}{8}$ in. and $\frac{1}{4}$ in. diameter for this piloting work, and a stand, within easy reach of the drilling machine and holding these drills and the Slocomb drills, will be found a great convenience.

Cross-Drilling Shafts

Accurate drilling through the diameter of a round shaft is frequently called for in the workshop, but is often inaccurately performed.

There are two methods of doing this in common use; the first, and perhaps the better, consists in using a locating guide bush for the drill as in the case of jig drilling.

Users of screwing die holders fitted with guide collets have at hand a set of guide bushes, ranging from say $\frac{3}{32}$ in. to $\frac{1}{2}$ in. in addition to the B.A. sizes.

Fig. 13 shows how these collets are used, in conjunction with the machine vice, to give accurate location and guidance to the drill.

The smaller commercial collets of the Card type have registers of half-inch diameter, which are increased to $\frac{3}{4}$ in. diameter in the larger sizes.

When the work is held in the vice, suitable packing strips must be disposed between the shaft and the vice jaws, or between the collet and the jaws, to give central location and a firm grip of both components; and, in addition, a washer is placed under the head of the collet to prevent its tipping. If necessary, the shaft is packed up to bring it close to the underside of the guide.

Although this setting-up may be regarded as somewhat tedious, very accurate results are assured by using this method.

The second method is to clamp a V-block to the drilling table, in a position accurately centred on the line of the drill axis. This centering is carried out with the aid of a short rod with coned tip held in the drill chuck.

The shaft is clamped in place in the V-block, and the hole is drilled by using a Slocomb drill followed by a drill of the required size. However, in this case any inaccuracy of the drilling machine will be reflected in the final result, and accuracy

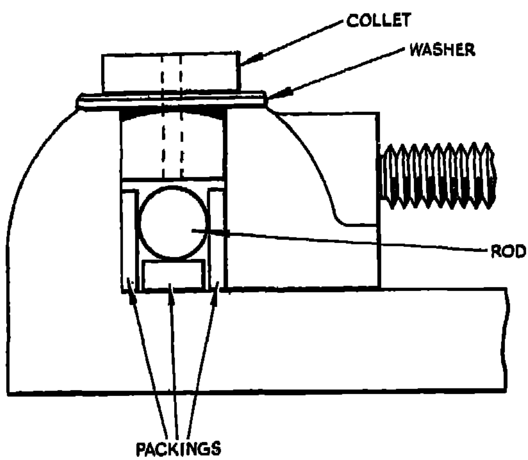


Fig. 13.

is rather more uncertain, as the point of the drill is not prevented from wandering at the start of the operation, nor is it guided through the work.

Countersinking, Counterboring and Spot-Facing

The tools used for these operations are described in Chapter III, and little need be said of their use, except that slow speeds should be used, and any tendency to chatter should be countered by still further reducing the speed of rotation.

When machining cast iron, the speed should be reduced to maintain free cutting with a moderate rate of feed, otherwise, if rubbing is allowed, the tool's cutting edges will be quickly blunted.

Tapping

If the drilling machine is provided with a spindle to hold Morse taper shanks, a commercial tapping attachment can be readily fitted, otherwise, taps may be held in the drill chuck for small work.

When machine taps are used, small nut blanks and other articles can be held in a fitting which prevents their rotation, but allows them to move upwards on completion of the tapping operation. In this way the nuts will come to rest on the plain shank of the tap when they have cleared the threads, and from time to time the tap is withdrawn from the chuck to remove the accumulated nuts.

Accurate tapping of small holes may also be readily carried out by rotating the drill spindle with a handle attached to its upper end. In this case removal of the return spring facilitates the operation, by allowing the weight of the spindle to maintain a downward thrust.

Lapping and Polishing

The drilling machine is convenient for lapping and polishing shafts, for not only can any desired speed be obtained, but also the abrasive material used tends to travel downwards out of harm's way, and not on to the bed and slides as in the case of the lathe.

The ends of small shafts and screw heads may be polished by feeding them against a strip of emery cloth, supported on a piece of wood or other compressible material on the drill table, but to avoid ringing the work the position of the abrasive material should be constantly changed.

In addition, where a high finish is required, small components may be rotated by the drill spindle and burnished with a strip of hardened and polished steel.

The so-called curled or whorl finish, as seen inside some watch-cases, may be applied to flat surfaces by using a polishing fitment held in the drill chuck and rotated at high speed.

A suitable device for this purpose consists of a short length of brass tube into which a small cork has been inserted. After the cork has been charged with a fine abrasive, it is pressed while rotating on to the work surface. An adjustable guide or fence may be used to ensure equal spacing of the lines of circles, and thus preserve the good appearance of the work;

while at the same time light pressure only should be applied, to avoid the danger of scoring the surface of soft metals such as aluminium.

Milling

Although the ordinary drilling machine is not designed with this purpose in view, and it is unwise as a rule to submit the spindle to side thrust, nevertheless, light milling operations at high speed can be successfully carried out without detriment.

For example, four-station ratchets, integral with $\frac{3}{8}$ in. diameter silver-steel petrol lighter wheels, have been satisfactorily machined in this way.

For this operation two small mechanical slides, provided with suitable stops and an indexing gear, were mounted on the table of the Model Engineer drilling machine, and a $\frac{3}{32}$ in. dental end mill was rotated at high speed in the drill chuck.

These cutters are of high quality and, as they have a slender neck above the teeth, only very light cutting pressure can be applied to the cutter and the drill spindle.

In this way the ratchet teeth were rapidly cut with an excellent finish, and the cutter maintained its sharpness and free-cutting qualities throughout.

CHAPTER VII

MILLING, SHAPING AND PLANING MACHINES

The Milling Machine. The Horizontal Milling Machine. The Dividing Head. Rotary Table. Vertical Milling Attachment. Slotting Attachment. Operating the Milling Machine. The Vertical Milling Machine. Equipment for Milling Machines. Shaping Machines. Planing Machines. Tool Equipment for Shaping and Planing Machines. Shaping Machine Operations.

The Milling Machine

When machining operations are performed by using rotary cutters, other than drills, the process is usually termed milling.

For some of these operations cutters akin to circular saws are used in the horizontal type of milling machine, which is capable of carrying out a wide range of work with a high degree of accuracy; for example, cutting spur gears, machining keyways, and cutting profiles of various forms.

As distinct from the horizontal milling machine, the vertical milling machine with its upright spindle is used for cutting keyways and T-slots, and for machining angular surfaces and guide-ways.

The latter machine is similar in some respects to a drilling machine, except that it is more rigidly constructed in order to withstand the side-thrust imposed by the form of cutter generally used.

Formerly, milling machines were of comparatively simple construction and were designed to be driven by belt from the workshop lineshaft, but now the more common practice is to operate the machine by means of a built-in electric motor, which, except in the largest machines, provides not only the drive for the main spindle but also operates the feed mechanism and the suds pump.

The Horizontal Milling Machine

These machines are divided into two classes: the plain and the universal type. The former has its work table fixed at right angles to the centre line of the machine spindle, whilst in the latter the work table can be set at any required angle to the spindle centre line. By means of this adjustment, work such as the cutting of skew gears can be carried out.

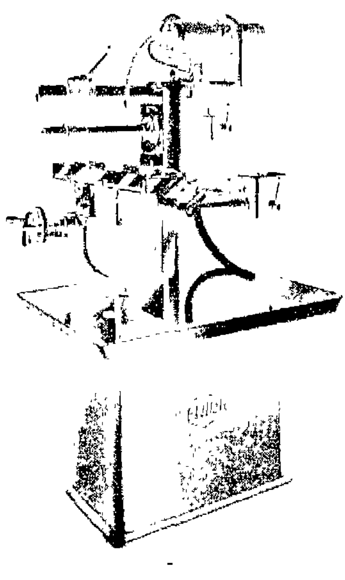


FIG. 1.

In order to make clear the construction and working of a horizontal milling machine, it is proposed to describe a representative machine of modern design, together with the additional equipment required to make full use of its possibilities.

Fig. 1 shows a plain milling machine made by Messrs. Tom Senior, which is specially designed for accurately carrying out a wide range of work in the small workshop or tool room.

As will be seen, the body of the machine is a box casting similar in many respects to that used for the headstock of

many modern lathes. The driving motor is bolted to the top of this casting, and the drive by V-belt is taken from the motor to a countershaft at the back of the machine, and thence by a two-step pulley to the main spindle, as shown in Fig. 2. The latter drive is enclosed in the box casting as shown in Fig. 3, where the arrangement of the back gear mechanism is also depicted.

As it is seldom possible to mount the cutters on the milling arbor in a position close to the main spindle bearing, it is

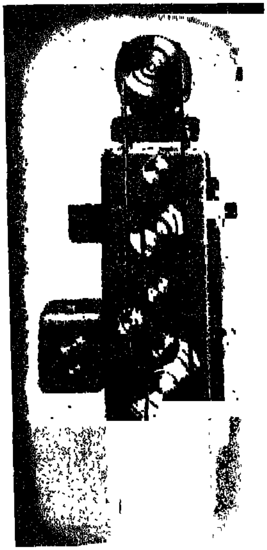


FIG. 2.

FIG. 3.

necessary to provide some means of supporting the free end of the arbor, to prevent it from being thrown out of alignment by the pressure of the cutting operation.

This is effected by providing an overarm, attached to the main casting in true alignment with the spindle itself; clamped to the overarm is an adjustable bearing member, in which the outer end of the arbor rotates when driven by the main spindle.

The arbor itself consists of a central spindle with a tapered end to engage the taper in the main spindle.

Fitted to the arbor spindle is a series of accurately made spacing collars or distance pieces which are used to position the milling cutters as required; at times, two or more cutters may be ganged together to promote accurate and rapid machining.

These arbor collars are ground truly concentric so that they and not the arbor spindle are made to run in the overarm bearing.

In order to provide an automatic feed for the work table traverse, a small gear box, chain driven from the countershaft, is fitted to the side of the main casting, and a universally jointed shaft carries the drive thence to the table through gearing which provides three rates of feed.

The spindle, which is bored No. 3 Morse taper, runs in adjustable Timken taper roller bearings.

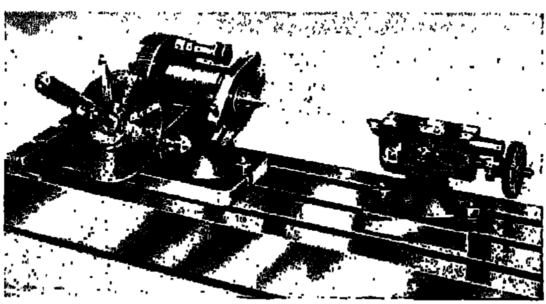


FIG. 4.

The front face of the box casting, through which the spindle projects, is machined in the form of guide-ways on which the knee or bracket carrying the saddle and machine table can slide.

The knee is of robust construction and is furnished with a screw-operated mechanism for raising and lowering the machine table; in addition, a cross slide is fitted to the knee for adjusting the work during machining.

All the slides have micrometer indexing collars fitted to their feed screws.

The machine has a wide range of spindle speeds, twelve in all, ranging from 50 to 1,660 revolutions per minute, and the available feeds per revolution of the spindle are 0.0045 in., 0·009 in. and 0·018 in.

The longitudinal travel of the table is 15 in. and the cross travel 6½ in.

With the addition of an accurate machine vice and suitable milling cutters, the machine is capable of undertaking a wide range of plain milling work, but, if it is desired to index-mill components such as gear wheels and splined shafts, it is then necessary to carry the work in a dividing head of the type shown in Fig. 4.

The Dividing Head

As the name implies, the purpose of this device is to enable the circumference of a component to be divided into any desired number of equal parts, and the construction and operation of the attachment are similar to those of the device used in conjunction with the lathe mandrel, and fully described by the authors in the book entitled *Lathe Devices.*

In the case of an attachment specially designed for use with the milling machine, the device consists of two components: a headstock and a tailstock as illustrated in Fig. 4.

The headstock carries the dividing mechanism attached to the spindle or mandrel, which has a threaded nose for the attachment of a chuck or driver plate. The spindle is also bored to a definite taper, such as Morse or Brown & Sharp, to facilitate the fitting of attachments or a tapered centre for use when machining work between centres.

The tailstock like that fitted to the lathe is provided with a screw feed, and its spindle carries a coned centre. The two units have tenons, accurately fitted to engage the T-slots of the machine table, to ensure that both are maintained in true alignment when clamped in position.

Rotary Table

At times it is required to machine radial slots in a component or to form a profile to a given radius; this may be readily carried out by mounting the work on a rotary table of the form shown in Fig. 5.

The work table is rotated by means of a handle operating a worm which engages a worm wheel attached to the base of the table.

The table can be locked if desired, and, to facilitate accurate setting, the periphery of the table is graduated in degrees.

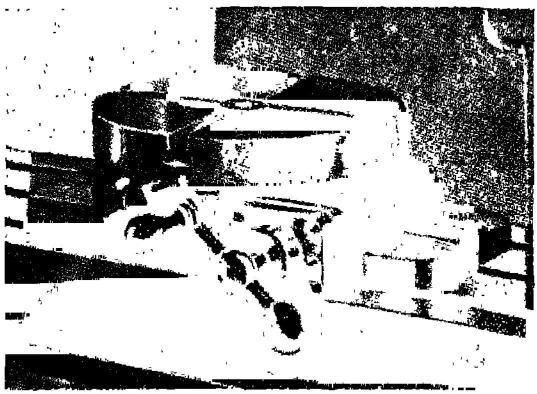


Fig. 5.

Fig. 6.

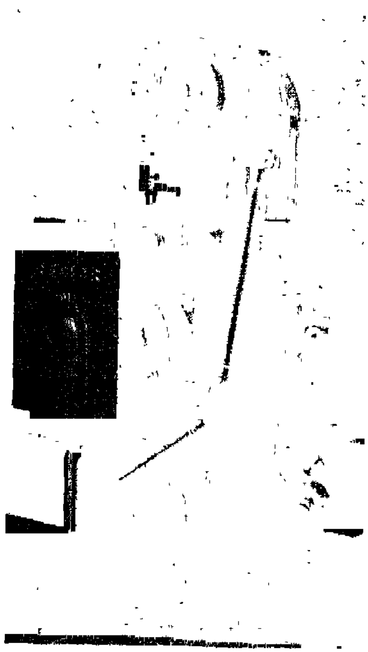


Fig. 7.

Vertical Milling Attachment

When there is insufficient work to justify the installation of a vertical milling machine, the addition of a vertical attachment to the horizontal milling machine may suffice for the needs of the small workshop.

As will be seen in Fig. 6, this device consists of a casting which can be bolted to the face of the machine in alignment with the main spindle housing. Spiral gears are fitted within the device to rotate the vertical spindle at the same speed as the milling machine spindle.

The gear spindles run in ball-bearings, and the machine spindle is bored No. 2 Morse taper.

End-mill cutters may be mounted in a suitable chuck, or held directly in the taper spindle and secured by a draw bar to prevent slackening under load.

The base of the attachment is graduated in degrees, and the head can be set in any desired position to enable angular machining to be carried out.

Slotting Attachment

This device, which is illustrated in Fig. 7, has the same method of mounting as the vertical attachment, and is used for the accurate and rapid cutting of keyways on the inner face of gears and collars.

The head is provided with a mechanism which enables the stroke to be adjusted from zero to the maximum of $2\frac{1}{2}$ in.

In addition, the attachment can be operated in any position to facilitate the machining of work mounted in the horizontal position, or at an angle to the vertical.

Operating the Milling Machine

Space does not here allow a description of milling operations, but this extensive subject is fully dealt with in text books such as Messrs. Brown & Sharp's *Practical Treatise on Milling*, or Messrs. Percival Marshall's *Modern Milling Practice*. Both of these publications also give full details of the construction of modern milling machines.

The Vertical Milling Machine

Vertical milling machines have been mentioned earlier in the chapter, and, as has been said, they resemble drilling machines but are of more robust construction.

Although the vertical milling machine usually employed in industry is comparable in size with the horizontal machine already described, small precision type machines such as the Boley, Lorch and Mikron are also manufactured, and these may be found adequate for undertaking the machining normally encountered in the small experimental or instrument-making workshop.

A representative small vertical milling machine is illustrated in Fig. 8. This machine has a headstock mounted on a vertical slide that can be operated by either a screw or a lever feed,

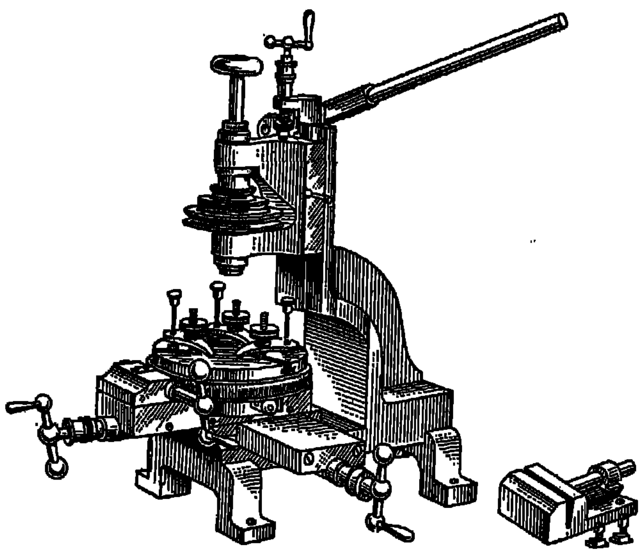


FIG. 8.

and on the feed screw is a nut that can be adjusted to give any depth of feed desired, whilst the slide can be fixed in any position by means of the small locking lever on the right.

The headstock has a draw-in spindle to take collet chucks similar to those with which precision lathes are equipped.

The work table is furnished with two slides at right angles to each other, and the upper slide carries a circular rotating table some 5 in. in diameter operated by a worm and worm wheel. This table is graduated to 360 degrees, and its upper surface is provided with T-slots for clamping work or for attaching a machine vice.

Whilst the speed at which the machine is driven by an electric motor of some ¼ horse-power will depend on the class of work being machined, a maximum speed of 5,000 revolutions per minute will usually suffice.

This machine may in addition be used as an accurate high-speed drilling machine, and in this case the lever mechanism will be found convenient for the sensitive feed of the drill.

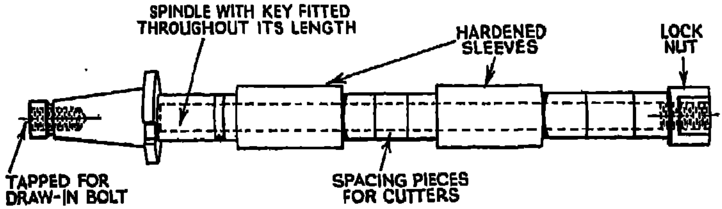


FIG. 9 (A).

Equipment for Milling Machines

Although the more elaborate attachments for enhancing the utility of the milling machine have been dealt with, the equipment essential for simple milling operations remains to be described.

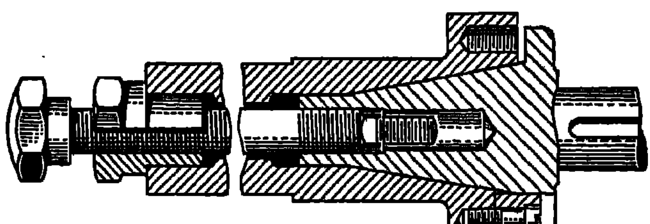


FIG. 9 (B).

The Machine Vice. This is perhaps the most useful item of extra equipment, and it is important that the vice should be accurately made, with the jaws truly square with the base, to ensure that the work is correctly held when the jaws are fully tightened. In addition, to save space, the overall height of the vice should be small, and the base should be so constructed that it can be easily and firmly bolted to the table without distortion arising.

Mandrels and Arbors. In order to accommodate the wide range of cutters available, a series of arbors should be provided to fit into the nose of the machine spindle, and be there secured by means of a draw-spindle.

Fig. 9A shows the usual type of arbor for general use, whilst Fig. 9B depicts a section of a standard Brown & Sharp spindle end and also shows how the arbor is secured in place.

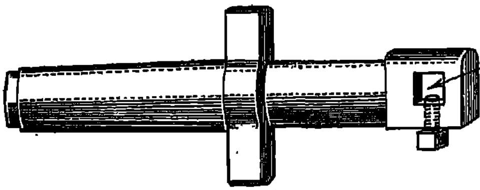


FIG. 10.

Fig. 10 represents an arbor specially made for carrying a fly-cutter of square-section tool-steel and having a single cutting point. These cutters are formed to suit the work undertaken, and, as the tool form is accurately reproduced on the work, they may be used for cutting profiles.

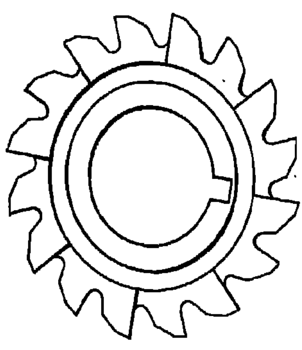


FIG. 11.

Fly-cutters have the advantage that, unlike circular milling cutters, they can be readily sharpened and honed to a fine cutting edge without the use of special appliances.

Milling Cutters. Here, again, space permits only of alluding to the more generally used forms. In the first group, represented by the example shown in Fig. 11, are metal slitting saws, side and face cutters, involute gear cutters, hobs, thread mills, corner-rounding cutters, and angle cutters.

The end-mills, which are generally used for slot-milling and keyway cutting, occupy the second group.

End-mills are usually of the type shown in Fig. 12, although some have spiral flutes instead of the straight flutes shown in the illustration, whilst others again have but two cutting lips as opposed to the form depicted.

The two-lipped end-mill is especially suitable for machining aluminium alloys, as it does not tend to become clogged by the swarf produced when cutting.

In connection with all milling cutters, it must be emphasized that the accurate and keen sharpening of these tools is essential if good work is to result from their use. For this reason, unless proper appliances are available, the cutters should be sent for sharpening to a firm which specializes in this highly skilled work.

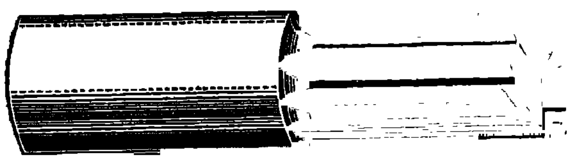


FIG. 12.

It should also be pointed out that it is essential that milling cutters should run truly, otherwise all the cutting may be done by a single tooth and the multi-tooth cutter in action becomes a fly-cutter.

Great care should therefore be taken to ensure that arbors are perfectly clean when cutters are mounted, and that adapters used to carry end-mills are free from particles of metal that might cause untrue running.

Shaping Machines

Shaping machines are often used in the tool rooms of engineering works to produce single components for experimental machines, and also to plane machine slides and tables and to cut keyways.

A simple form of shaping machine is shown in Fig. 13; this hand-operated machine was at one time manufactured by Messrs. Tom Senior.

The construction of the machine, which will be clear from the illustration, consists of a pillar stand on the top of which is

bolted a box-type body heavily ribbed within. The body has integrally-machined slide ways on which the carriage carrying the ram of the machine moves.

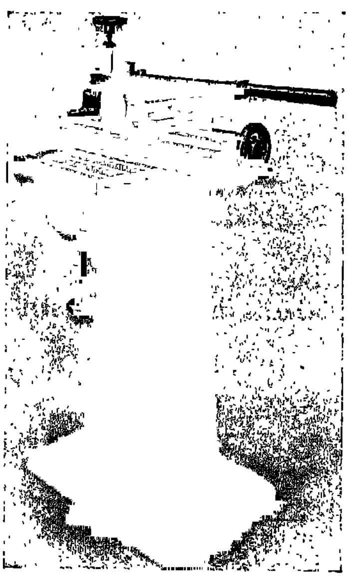


FIG. 13

The carriage is free to move along the body slides under the control of the feed screw, which is actuated either by a hand wheel, or by an adjustable pawl and ratchet mechanism for automatic feed.

The ram head, which is bolted to the ram, is provided with a means of angular adjustment and carries a slide for feeding the tool-box down to the work.

As in all shaping machines, the tool post or clapper box is hinged to provide relief for the tool on the backward stroke. The tool post may also be set at an angle independently of the ram head.

On the front of the box pillar are bolted the work table, and the hand wheel and feedscrew mechanism for raising and lowering the table. The bolting face on the pillar is actually a machined T-slotted surface which can be used for securing awkward work for machining.

The work table of this machine measures 12 in. by 7 in., and the stroke of the ram is 8 in., whilst the traverse of the carriage is 12½ in., and the vertical travel of the table 3½ in.

The machine is operated by means of the hand lever seen above the ram, and movement is imparted to the tool by means of an adjustable toothed quadrant, secured to the lever, and a rack bar attached to the ram.

The Drummond hand shaping machine, although no longer manufactured, is a very accurate and well-designed machine.

The ram, which has a stroke of 7 in., is carried in adjustable guide-ways machined in the body, and the work is attached to a traversing carriage having automatic feed in either direction. In addition to the usual T-slots, the work table is provided

with circular T-slot ways to accommodate the special rotating machine vice supplied.

The knee bracket which carries the carriage is equipped with a hand wheel and screw mechanism for raising and lowering the table. Both the ram head and the tool slide carrying the clapper box are adjustable for angularity.

The machines described above are representative of the hand-operated type of machine, but power-driven shaping machines are of the same general construction, although in those intended for heavy duty the ram is not carried in a movable carriage, but has its slides integral with the body as in the case of the Drummond machine; in addition, a box-form table is usually fitted to afford greater rigidity and to facilitate the mounting of large work.

Power shaping machines vary greatly in the complexity of their design, the difference being mainly connected with the number of speeds and feeds provided.

In all types of these machines, with the exception of the simplest, the stroke of the ram is adjustable by means of a connecting rod, fitted with a movable crank pin secured in a slotted crank disk.

The more elaborate machines have a quick return motion which provides for the rapid return of the ram on its idle stroke.

Planing Machines

The planing machine has, as a rule, a long stroke, and is used for machining articles, such as lathe beds and engine bed plates, which could not well be accommodated in a shaping machine.

These machines operate in a manner similar to shaping machines, except that in the case of the planer the work table moves to and fro, and the tool holder and tool head remain stationary.

The long work table slides on the guide-ways machined in the main body casting, to which are bolted two uprights carrying the cross slide with its adjustable tool slide and tool holder. The cross slide is equipped with an automatic traversing gear actuated by the crank mechanism.

Power-operated planing machines are built in many types, and the largest are machines of great size; as in the case of shaping machines, the more elaborate designs have a quick

return gear to accelerate the motion of the work table on its idle or return stroke.

Tool Equipment for Shaping and Planing Machines

In the matter of tool equipment, shaping and planing machines have the advantage of using tools which are easily formed and sharpened, whereas, as has already been pointed out, special appliances are required for sharpening the circular cutters employed in milling machines.

The tools generally used in the former machines are similar to lathe tools, and equivalent cutting and clearance angles should as a rule be employed, in accordance with the character of the work and the nature of the materials machined.

As in the case of the lathe, it is important to limit the area of contact of the tool's cutting edge in keeping with the rigidity of the machine, otherwise inaccurate work with a wavy surface may result.

When a tool of lathe type is used there is a tendency under heavy load for the cutting edge to spring deeper into the work; this may be overcome by so forming the tool that the cutting edge lies behind the axis of the shank, and the point when under stress will then tend to rise from the work.

Shaping Machine Operations

When machining flat surfaces the need for adopting a limited contact area of the tool with the work has been pointed out, in order to maintain accuracy and a good finish; in addition, the cutting angle of the tool must be adjusted to avoid tearing the surface, or opening the grain when machining cast iron.

When angular surfaces such as the undercut guide-ways of machine slides have to be machined, the ram head is set over to the required angle and the tool is fed downwards by the tool slide; but when machining in this way it may be found that on the return stroke the tool rises, owing to the action of the clapper box, and jams in the work.

In this event, a bridge piece must be fitted to the clapper box to prevent its movement; this device is also required when the shaping machine is used to cut on what is normally its return stroke.

For cutting keyways within pulleys or gear wheels a short boring bar, carrying a square-ended tool, is fixed in a holder

and clamped in the tool post, and, to avoid the tendency of the tool to dig into the work, it is preferable to pull rather than to push the tool on its cutting stroke; in this case, as has already been pointed out, it is necessary to clamp the clapper box to prevent its movement. This keyway cutting operation is sometimes carried out by securing the work to the ram head, and clamping the tool in a bracket fixed to the machine table.

Spur gears can be machined in the shaping machine by employing an accurately formed profile tool provided with adequate clearance.

In this case, the gear blank is mounted on the machine table in a fixture which carries a master gear and a detent for indexing the teeth.

A lathe change wheel may be used for this purpose, and during machining both the gear blank and the machine carriage must be firmly secured against inadvertent movement.

Racks can be machined in the same way with a profile tool; the work is secured in the machine vice, and the teeth are spaced by traversing the machine table with reference to the micrometer index on its feed screw.

CHAPTER VIII

TOOL GRINDING

Equipment. Drill Grinding Jig. Tool Grinding Rest. Grinding Wheels. Mounting Grinding Wheels. The Use and Care of Grinding Wheels. Forming and Sharpening Tools. Grinding Drills. Miscellaneous Grinding Operations.

Equipment

ALTHOUGH no very elaborate or expensive equipment is required for grinding the tools and drills used in the small workshop, it is essential that this should be capable of producing accurate results and a fine finish to the work, in order that the tools so ground can carry out their respective machining operations to the best advantage.

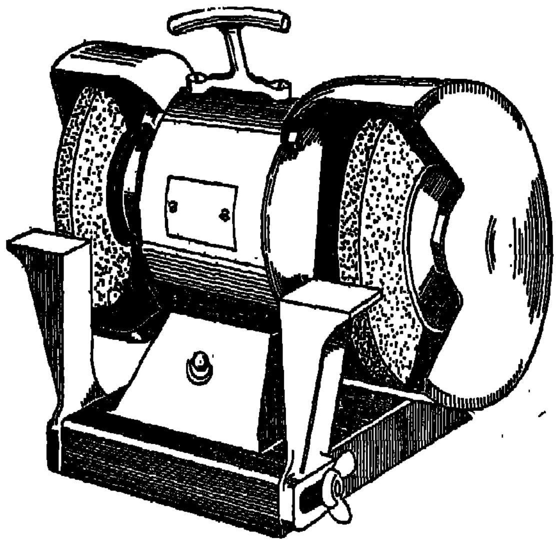


FIG. 1.

At the outset, it must be emphasized that the finished cutting edges of the tools should be really sharp, in the sense that a knife is said to be sharp, for to force a blunt tool to cut metal or other material can result only in inaccurate and roughly finished work.

In addition, to obtain the best results, the tool's cutting edges should appear uniformly sharp and free from gaps and ridges when examined with a magnifying glass.

A very convenient form of self-contained tool grinder is shown in Fig. 1. An electric motor carries an abrasive wheel on either end of the extended armature shaft, and the motor is so constructed that it runs at the correct speed for the wheels with which it is furnished.

The two wheels are of coarse and fine grain for roughing and finishing grinding respectively.

The tool rests are adjustable for angularity in relation to the periphery of the wheels, and are set at right angles to the side faces of the wheels.

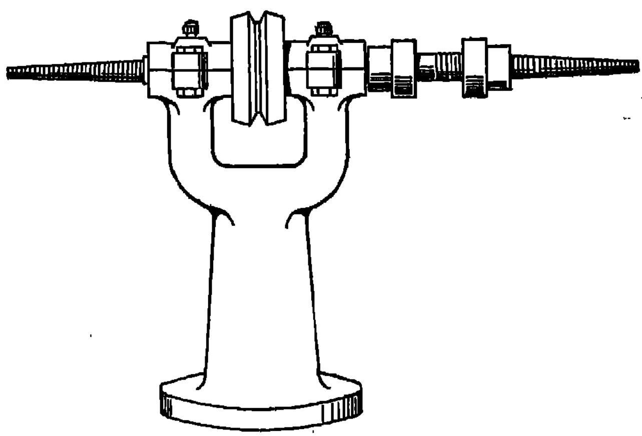


FIG. 2.

Although these grinding machines greatly facilitate the work of sharpening tools, and can in addition be moved from place to place as required, the initial cost may not seem justified where a power drive is already available, and, moreover, a simpler type of grinding head may be adequate, or even preferable, if the addition of a drill grinding jig is contemplated.

The simple and inexpensive form of grinding head, shown in Fig. 2, can be readily equipped with any special grinding rests or jigs required.

The low initial cost of these machines precludes the precision fitting and finishing of the journals and bearings, and as a result they may not run quietly at high speeds, but the refitting

of these parts is easily carried out, and will be well repaid by the resulting quiet running and longer bearing life.

To ensure that the bearings in the cast-iron body are in true alignment, the casting should be set up on the lathe boring table, as shown in Fig. 3, and the bearings are rebored with a boring bar mounted between the lathe centres.

If the bearings are of the split type, brass packing strips should be first fitted and the adjusting screws firmly clamped.

While still in this position, the bearings are reamed and then lapped with an adjustable lap driven by the lathe mandrel. To avoid side-thrust, the lap should be driven by a flexible

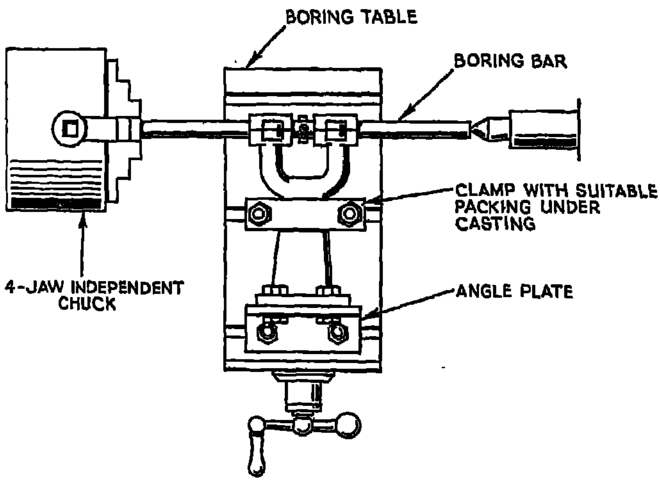


FIG. 3.

coupling of heavy rubber tubing or by a coil spring, and the lapping process is continued until the bearings are truly parallel and have a uniformly fine finish.

The end surfaces of the bearings should also be accurately faced to ensure proper end-location of the spindle.

A new spindle is turned from good quality alloy steel and is lapped to fit its bearings accurately.

To prevent the ingress of abrasive material into the bearings, felt washers may be fitted to the central portion of the spindle. These washers are held in place by the pressure of a light coil spring as shown in Fig. 4.

The fitting of an adjustable tool rest and a drill grinding

jig will be facilitated by mounting a single abrasive wheel on the spindle, and using separate grinding heads for roughing and finishing work, and, moreover, the provision of left-handed threads for the spindle and clamping nut will thus be avoided, whilst the drive for the over-hung pulley can, if desired, be arranged to come from below the bench top.

In this case, both grinders may be driven by a single electric motor, if one is fixed to the bench top on a base which is made to unclamp and slide out of the way when not in use. Such an arrangement is described and illustrated in Chapter IV.

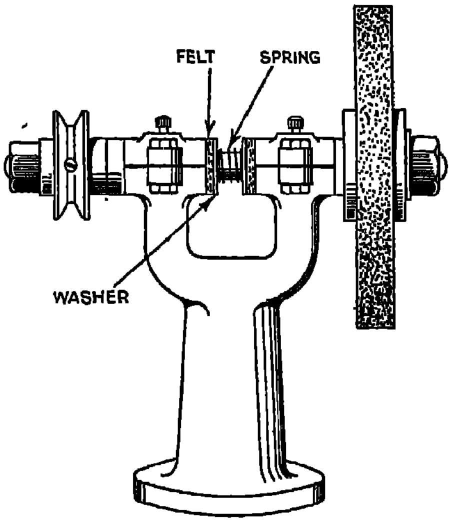


FIG. 4.

For grinding the smallest tools, a small India wheel may be used when mounted directly on the armature spindle of a fractional horse-power electric motor.

Here, too, a suitable tool rest must be provided, and, if in addition a means of sharpening the smaller sizes of twist drills is required, a bracket to carry the drill grinding jig may be fitted.

Drill Grinding Jig

As frequent sharpening of drills is essential for good work, and as this can only be carried out quickly and accurately

by the use of a jig, provision should be made for incorporating this device in the grinding machine.

The Potts drill grinding jig, shown in Fig. 5, is fixed to the bench top by means of a base bracket. This bracket can also be conveniently used to attach an adjustable tool-grinding rest. If, therefore, the two grinding heads are each provided with a bracket of this type, the drill jig or the tool rest can be used with either the roughing or the finishing wheel at will.

In addition to its ease of attachment to the grinding machine, the Potts jig is an accurately made device suitable for sharpen-

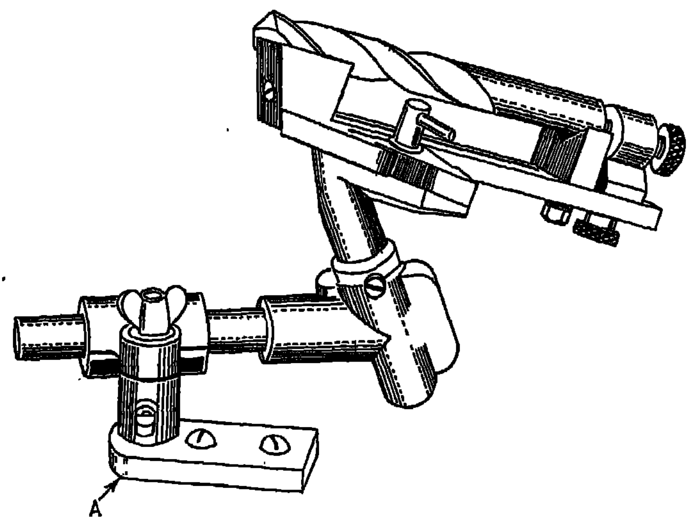


FIG. 5.—Potts Jig.

ing centre drills as well as twist and straight-flute drills up to ½ in. diameter.

The provision of a calliper setting-gauge in the sliding head ensures grinding the correct back-off on drills of all sizes within the capacity of the device, and, moreover, the back-off can be varied as required to suit drills used for special purposes.

Tool Grinding Rest

The usual practice of the machinist is to use the periphery of the wheel for tool grinding, and for this purpose the machine illustrated in Fig. 1 is equipped with a swinging type of tool

rest, which may be set to alter the angle at which the tool is presented to the wheel, or, in other words, its height above the wheel centre. Adjustment of this setting will form the required angularity of the tool's edge.

This method of tool grinding has some disadvantages, for not only must the setting of the rest vary with the size of the tool, and with the reduction of the wheel's diameter due to wear, but in the case of the smaller diameter wheels, the concavity produced may seriously weaken the tool's cutting edge.

The former consideration renders calibration for setting the rest far from easy, but this may be facilitated by using a set of gauges or templates, formed in accordance with the size of the tools and the angles to be ground.

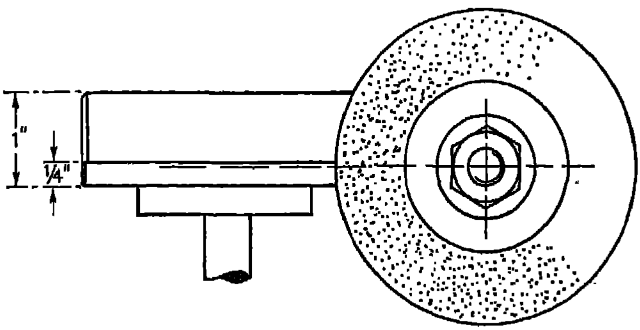


FIG. 6.

Fig. 6 illustrates diagrammatically the effect of grinding tools of ¼ in. and of 1 in. section with the rest set a little below the centre of the wheel; the front clearance formed is excessive for the 1 in. tool, and of negative value in the case of the ¼ in. tool.

An alternative method of tool grinding is to use the side faces of the wheel and to set the rest to the required angles by means of sheet metal gauges, which are held vertically on the tool rest by means of a detachable base.

A set of these gauges should be made and marked with the angles they represent. If a tool has to be finish ground to say 10 degrees, it will facilitate the work and lessen the possibility of undue heating if the edge is first ground to 11 degrees on the roughing wheel.

Fig. 7. shows a gauge of this type mounted in a convenient form of spring-grip base made by the Starrett Co., and as will be seen, the gauge is made double-ended to serve both grinding operations.

As has already been mentioned, the type of base bracket

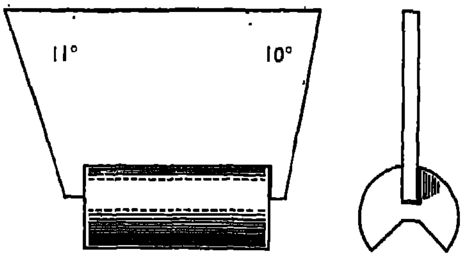


FIG. 7.

which is used to hold the drill grinding jig may also be used to support the tool grinding rest.

The tool rest, shown in Fig. 8, was designed to allow either the periphery or the flanks of the grinding wheel to be used, and in addition to afford accurate angular setting in relation to these wheel surfaces.

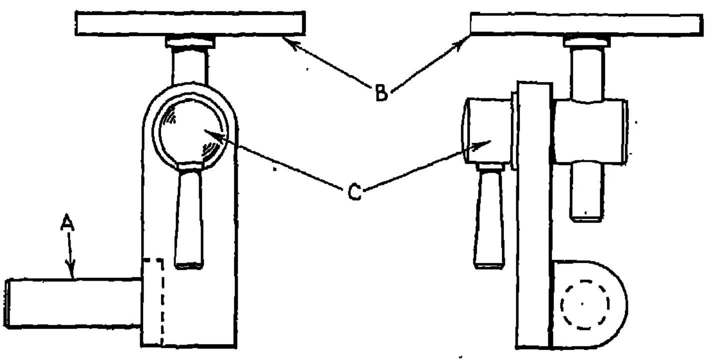


FIG. 8.

The grinding table should be scraped flat to prevent the tool from rocking, and may also be case-hardened to lessen wear from abrasive dust.

The cylindrical bar (A), which is a sliding fit in the bracket shown in Fig. 5 at A, can be locked in position, after adjustment, by the bracket clamp screw.

To allow of both angular and height adjustment, the shank of the table (B) slides in the pivot bolt (C), which is provided with a cross-drilled clamping collar at its further end.

When using the periphery of the wheel, the tool rest is clamped vertically, or by reference to an index line, and the table is adjusted until it is at the required distance above the wheel centre-line to grind the desired angle on the tool. To facilitate this adjustment, the tool rest shank may be graduated, or a setting gauge may be inserted between the lower surface of the rest and the upper face of its bracket, or, as previously mentioned, a template may be used on the grinding table.

When these dimensions have been determined for grinding the required angles on the different thicknesses of tools used, a table should be prepared for future reference.

When, on the other hand, the sides of the wheel are used for angular grinding, the rest is set from the wheel face by means of the gauges already described, or, if desired, a scale in connection with the pivot bolt can be devised to indicate the angular position of the table in relation to the wheel.

As will be apparent, the rest is adjusted laterally to clear the grinding wheel by sliding the shank (A) in the base clamping bracket, and radial clearance is obtained by rotating the device in the bracket. A tool rest of this type, which affords such a variety of adjustment, greatly facilitates accurate tool grinding, and, in addition, has other applications to which reference will be made later.

Grinding Wheels

Although there are many manufacturers of grinding wheels, the standards adopted by them for classification are now almost universal; but of the vast number of varieties of abrasive wheels made, only those of general utility in the workshop need be mentioned, for reference to the manufacturers' lists and handbooks will furnish any further information required.

The abrasives most used in the composition of these wheels are Aluminium Oxide and Silicon Carbide, of which the former is the more generally used by virtue of its greater adaptability in the workshop.

The fineness or coarseness of the wheel is indicated by the size of the individual abrasive grains, which are numbered according to the size of the mesh per inch through which they have passed; thus 60 is a fine medium grain suitable for

the finish grinding of tools, whilst 30 is a coarse medium grain useful for rough grinding.

The abrasive grains are embedded in a bonding substance, which retains the grains in place, but at the same time allows them gradually to break away under the stress of grinding, and so expose fresh sharp grinding particles.

It is by this tenacity to retain the grains that the hardness of the bond is measured.

Of the two types of bonding in general use, the vitrified and the silicate, the former is better suited for rough grinding and for ordinary workshop use.

The letter H denotes that the bonding is hard, M that it is of medium hardness, and S that it is soft, whilst D indicates very hard and W very soft bonding material.

The intermediate grades are represented by the intervening letters of the alphabet.

For off-hand rough grinding the Carborundum Co. advise the use of an Aluminium Oxide wheel with vitrified bonding of H to K grade of hardness, and of a grit or grain size of 24 to 40, whilst for fine work a similar wheel of J to M grade and 50 to 80 grit is recommended.

For sharpening Tungsten Carbide tools a Green Grit type of wheel is necessary, but if, after grinding, the tool edge is examined with a high-power magnifying glass, it will appear rough and jagged, and as this edge is very brittle, it will deteriorate rapidly in use.

Tungsten Carbide can, however, be lapped to a smooth razor-like edge, with good wearing qualities, by finish grinding on a diamond dust lapping wheel.

For sharpening scribers, dividers, small centre punches and the smallest sizes of cutting tools, the ordinary abrasive wheel will be found too coarse and will cut too quickly to give good results.

For this purpose, it is better to use a very fine grit wheel of small diameter such as the India, which is made of artificial abrasive and a bonding material which readily absorbs oil. When the wheel revolves, this oil is carried outwards by centrifugal force and prevents overheating in addition to promoting a fine finish on the work.

Mounting Grinding Wheels

The lead bush incorporated in the wheel must be an easy fit on the grinder spindle, otherwise, when the wheel and

the spindle become warm under working conditions, a bursting strain may be imposed on the wheel. If necessary, any high spots in the bore of the bush should be removed with a sharp knife.

The inner driving flange should be firmly fixed to the spindle in order to align the wheel, and the retaining nut should be tightened sufficiently to afford a secure drive, but without damaging the wheel by excessive pressure.

The flanges, of at least one-third the diameter of the wheel, should be recessed, as shown in Fig. 9, so that they grip by their peripheral portions only, and, to distribute the clamping pressure equally, soft paper disks should be interposed between the wheel and the flanges.

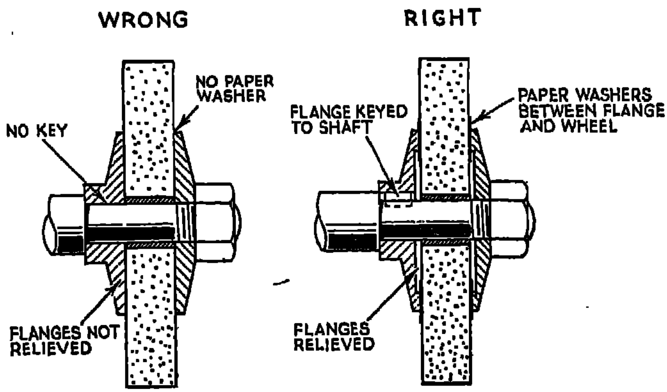


FIG. 9.

The Use and Care of Grinding Wheels

As it is essential for doing good work that the wheel should run truly, it will probably be necessary to true it with a diamond tool after first fitting, and again later should uneven running develop as a result of wear.

When starting a grinding machine, particularly after fitting a new wheel, it is wise to stand aside to avoid the danger resulting from wheel breakage.

For ordinary work, wheels are run at about 5,000 surface feet per minute, which is approximately 20,000 revolutions per minute in the case of a 1 in. diameter wheel.

Should the wheel tend to glaze, the speed should be reduced, but if the speed is too low more rapid wear and possibly loading of the wheel will ensue.

Glazing of the wheel surface takes place when the abrasive particles have become dulled and the bond is too hard or tenacious to allow them to be shed.

If this trouble tends to recur after the cutting properties of the wheel have been restored by dressing with a diamond tool, or with a disk or star-wheel cutter, the remedy is to use a lower speed or a wheel of softer bond.

Loading, on the other hand, may be caused by forcing the work against the wheel and so filling the interstices of the bonding material with metal particles, in the same way as a file may become clogged.

To remedy this condition, the wheel should be dressed to expose a fresh cutting surface, and it may be advisable to increase the wheel speed and to reduce the grinding pressure to avoid further trouble of this nature.

To promote quiet and accurate running, the spindle bearings should be kept correctly adjusted, and adequate lubrication of the spindle bearings is essential to prevent heating, with consequent risk of damage to both the spindle and the wheel.

If the side of the wheel is to be used for grinding, a wheel of adequate strength and thickness should be fitted, and care must be taken not to impose undue pressure at the risk of causing breakage.

Overheating of the tool edge must be avoided at all costs, for many tools are damaged in this way, but intermittent cooling in water is not good practice, as, when the water is vaporized by the heat of grinding, small surface cracks may be formed in the edge of the tool.

If a coolant is to be used, a proper system of wet-grinding should be employed.

To lessen the possibility of overheating, the tool should be kept moving when in contact with the wheel, and when several tools are being ground it is a good plan to grind each in turn for a few seconds only, to allow cooling to take place meanwhile.

Heating of the tool is more apt to occur when the surface in contact with the wheel is large, or when a fine grit wheel is used; as far as possible, therefore, keep altering the angle of presentation of the tool to the roughing wheel, and leave only the minimum of metal for removal by the finishing wheel.

The abrasive dust formed during grinding operations should be localized by means of a hood or guard fitted to the grinding

machine, but, if this is not effective, a sheet of cardboard, used as a screen, may serve to protect the workbench and so facilitate the collection and disposal of the abrasive material.

Forming and Sharpening Tools

Although the various tool-forms for different classes of work are standardized, and are depicted in text-books dealing with the subject, some modification of these forms may at times be an advantage, either for special work or to suit a particular machine.

To maintain output, the heavy manufacturing lathe is equipped with tools to remove the greatest amount of metal

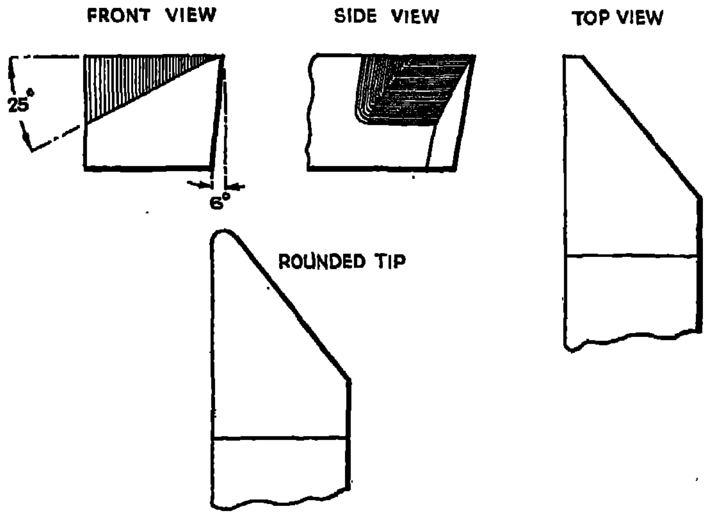


FIG. 10.

in the shortest time, consistent with accurate machining, but in the small workshop, where the machine tools are probably less rigid and the output of lesser importance, the tools used may be less sturdy but freer-cutting to impose less strain on both the work and the machines.

With this in view, and to avoid chatter and inaccurate work, the area of the tool's contact with the work is reduced and the cutting angles are made more acute to promote free-cutting.

For light work on mild steel the knife tool, shown in Fig. 10, has its side-rake increased to 25 degrees, and its side-clearance need not be greater than 6 degrees in view of the reduced rate

of longitudinal feed. A front-clearance of 10 degrees can be provided without materially weakening the point of the tool.

To give a good finish to the work, a flat is formed at the tip of the tool, but this must not be too great or chatter may ensue. Unless a sharp angle has to be formed on the work, the tip should be rounded, as shown in Fig. 10, to give greater strength to the tool point.

This form of tool is also well-suited for facing work.

It should be again emphasized that the cutting edge of the tool must be really sharp if good work is to be expected, otherwise particles will tend to break off from the edge, thus causing rapid blunting, which will result in rubbing and tearing of the machined surface.

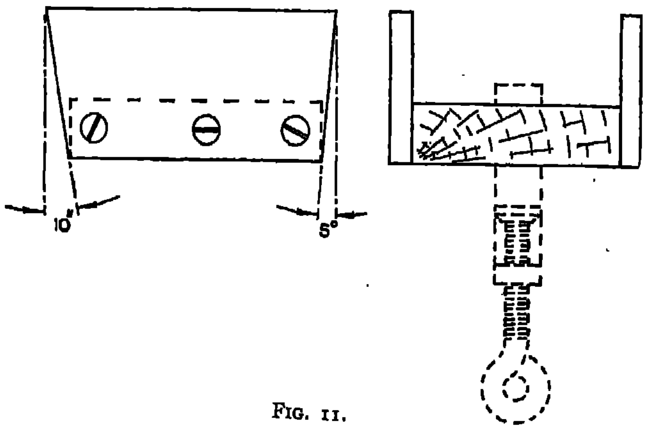


Fig. 11.

After grinding, therefore, the cutting edges should be finished on an oil stone, either by applying the tool to the stone, or by using a small oil stone slip held in the hand.

As the cutting edges may easily be rounded, and their efficiency thereby lessened by this procedure, if great care is not taken, it may be an advantage to use a stoning-jig of the form shown in Fig. 11. This jig is clamped to the bench and either the 5 degrees or the 10 degrees guide surfaces may be used at will, and furthermore, the tip of a parting tool, for example, may be honed to a right angle by using the side member of the jig as a guide.

When finishing the cutting edges of tools in this way, honing should be continued until all grinding marks have been removed.

Grinding Drills

When grinding twist or straight-flute drills, if much metal has to be removed, the coarse grinding wheel should be used prior to the finishing operation on the fine wheel; and in every case great care must be taken to avoid overheating the drill point by keeping the work moving in relation to the wheel surface, and by taking only fine cuts.

In the case of Slocombe centre-drills, the setting of the drill jig to form the correct back-off is best determined by a process of trial and error, and when found these settings should be noted for future reference.

When very short drills have to be ground, it may be necessary to interpose a distance piece between the drill shank and the feed-screw to make the latter operative.

Miscellaneous Grinding Operations

For grinding the ends of hardened shafts, bushes and springs, a V-block or other form of guide may be clamped to the grinding table, as shown in Fig. 12, and then adjusted to any angle required in relation to the grinding wheel.

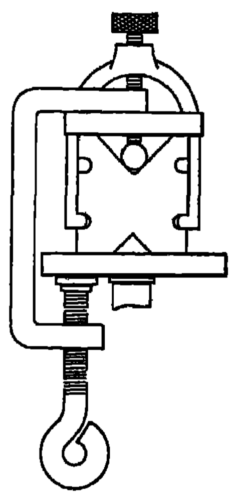


FIG. 12.

If an end-mill has to be formed from a broken twist or straight-flute drill, the V-block should be aligned truly at right angles to the wheel, and at the same time the grinding table is tilted to form the clearance angles necessary for the cutting edges of the tool.

The side of the wheel is used for grinding the cutting edges, and the rest is swung outwards until the periphery of the wheel cuts only as far as the centre line of the drill.

Indexing the two lips is facilitated by fixing a tap wrench to the shank of the drill, and turning it through an angle of 180 degrees to grind the second lip.

The grinding of the cutting edges should be continued until the application of a square shows them to be in line and at right angles to the axis of the tool.

The V-block guide can also be used on the grinding table

to perform operations such as grinding a square on the hardened shank of a machine tap, to make it suitable for use as a hand tap.

In this case, a square indexing piece is secured to the tap with a grub-screw, and the tap is clamped in the V-block with this indexing piece in contact with the face of the block. The arrangement is shown in Fig. 13.

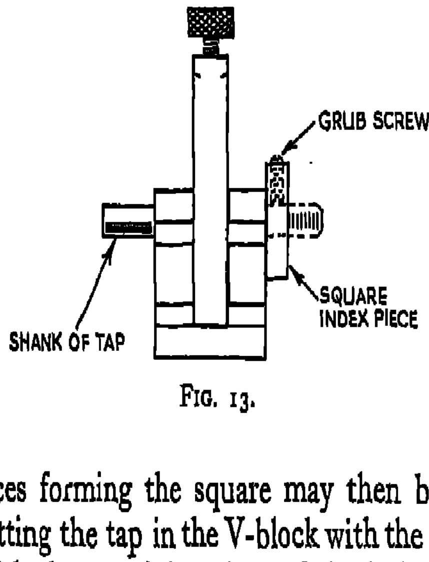


FIG. 13.

The surfaces forming the square may then be ground off-hand by resetting the tap in the V-block with the aid of a square in contact with the remaining sides of the indexing piece. If greater accuracy is required, two strips at right angles should be clamped to the grinding table to act as fences or stops, so that one limits the forward travel of the V-block and determines the length of the square, whilst the other sets the depth to which the flats are ground.

CHAPTER IX

FILES. HACKSAWS. SCRAPERS

Files. File Handles. Correct Height of Vice. Filing. Draw-Filing. Holding Work in the Vice. Cleaning Files. Storage of Files. Hacksaws. Hacksaw Frames and Blades. Using the Hacksaw. Hand Hacksawing Machine. Power-Driven Hacksaw Machines. Scrapers. Making Scrapers. Using Scrapers. Finishing Scraped Surfaces.

Files

ALTHOUGH the file is perhaps the most used hand tool in the workshop, careful selection and skilful application are required to obtain the best results.

In the first place, the file in its various forms is capable in skilled hands of doing work which for variety and accuracy is equalled only by elaborate machinery, but to acquire the skill requisite to obtain these results much patience and time must be expended, for to file a surface truly flat, for example, is a craftsman's art which in these days of mass production is in danger of being lost except in a few specialized trades.

The commercial file, made of tool-steel, has a blade on which the teeth are formed by a machine process, although formerly these were struck entirely by hand.

The blade is of varying shape according to the style of the file, and the number and pitch of the teeth varies also with the classification.

Although different manufacturers have their special grading in this latter respect, the number of teeth per inch is usually in accordance with the following table.

Rough	..	20 teeth per inch.
Middle	..	25 " " "
Bastard ..	..	30 " " "
Second cut	..	40 " " "
Smooth	..	50 to 60 teeth per inch.
Dead Smooth	..	100 or more teeth per inch.

Attached to the blade of the file, and formed integrally with it

during the forging process, is the file tang to which a wooden handle is usually fitted.

After the teeth have been cut, the blade of the file is hardened, but the tang is left in the soft condition to avoid the possibility of breakage at this point during use.

Files are also classed according to length, cut, and cross sectional form.

The length, which is the length of the blade only and does not include the tang, may be from 4 to 20 inches; for rough work a file of 10 to 16 in. is suitable and for fine work one of 4 to 6 in. in length.

Files may be either single- or double-cut. In the former case the teeth are cut parallel and usually at an angle of 60 degrees with the long axis of the blade, whilst in the latter

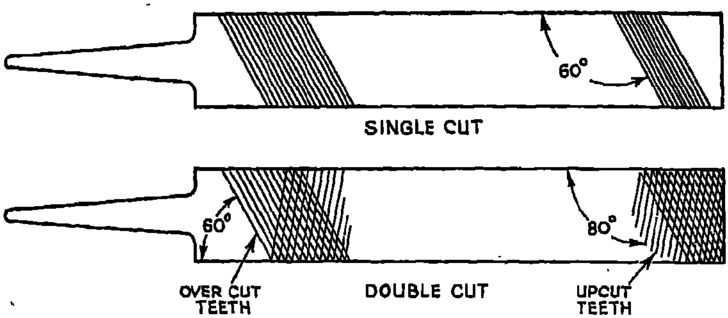


FIG. 1.

classification the first or over-cut teeth are formed at an angle of 60 degrees and are crossed by the second or up-cut teeth at an angle of some 80 degrees.

The two forms are illustrated in Fig. 1.

Although these angles are found to give the best results for ordinary work, manufacturers cut special files with alternative angles to suit particular materials.

Thus, for wrought-iron the appropriate angles are 30 degrees and 60 degrees, but for brass an up-cut angle of nearly 90 degrees is used.

The general and cross-sectional forms of standard files are illustrated in Fig. 2, and some of the less common varieties in Fig. 3.

In the case of the hand file, shown in Fig. 2, it should be noted that although parallel in width the blade tapers slightly

in thickness towards its extremities; in addition, one edge of the file is left plain and without teeth to form a safe-edge for use when filing into angles.

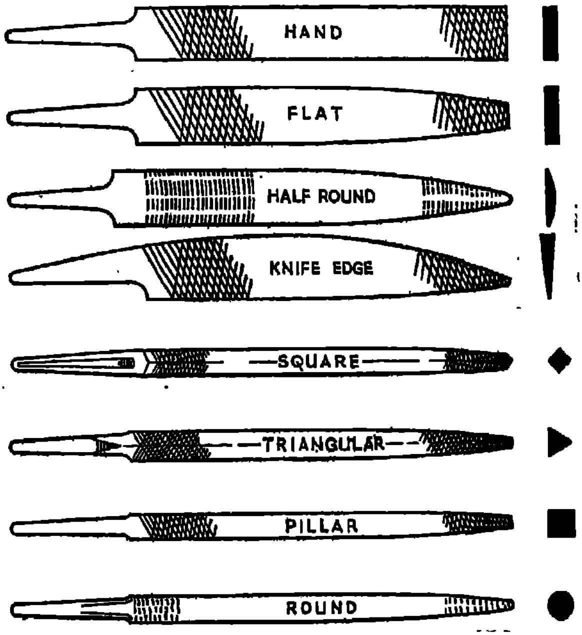


FIG. 2.

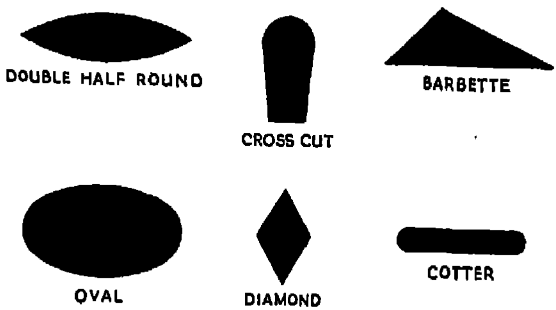


FIG. 3.

For delicate work needle files, as illustrated in Fig. 4, are made in lengths of from 4 to 8 inches.

When fine work is undertaken and a high finish is required, the form known as the Swiss file may be used with advantage.

These files, which have fine teeth and are made of high-grade steel, are obtainable in all the usual forms, but the standard length does not exceed 8 inches.

The coarseness of cut is graded from 0 to 6, representing a tooth pitch of from 50 to 200 per inch.

When it is necessary to file inside curved castings, such as the ports of an automobile engine, the Riffler type of file shown

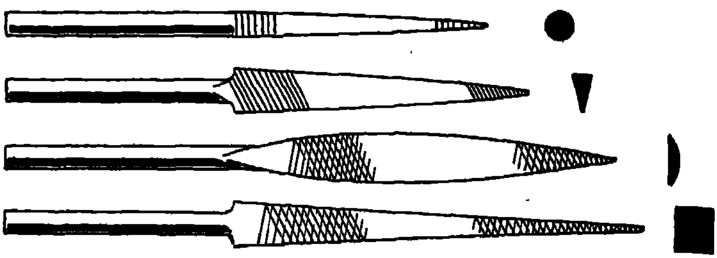


FIG. 4.

in Fig. 5 should be used. These files of nearly flat or of oval section are curved upwards at their ends to enable them to make contact with concave surfaces.

If desired, these files can be made in the workshop by heating an ordinary file to redness, and then setting it to the required form by striking it with a lead hammer whilst supported on

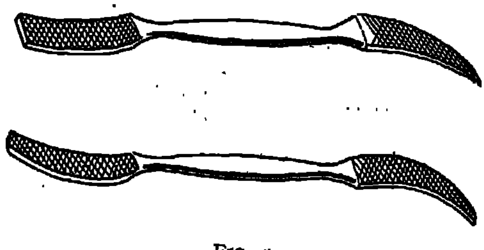


FIG. 5.

a lead block. After rehardening the blade the file will be ready for use.

Aluminium and aluminium alloys are difficult to file to a good finish unless special files are used, for this material is apt to adhere to the teeth and cause "pinning" of the file. To obviate this trouble, files of a special type known as milling files have been produced, of which the Dreadnought is perhaps the best known example.

The teeth of a milling file are cut across the blade in a slight curve, and as they are comparatively widely-spaced, there is ample clearance between the teeth for the chips to accumulate without clogging the file.

These files can be obtained as Hand, Flat, Round, Half-round, Three-square and Square, and the form of the cutting surface and of the tooth profile is illustrated in Fig. 6.

File Handles

To use a file to the best advantage it is essential that it should be fitted with a proper handle.

The size of the handle should bear some relation to the length of the file, for to use a heavy file efficiently a large handle fitting the hand comfortably should be used, whilst for fine filing with a small file the handle should be small to afford delicacy of touch.

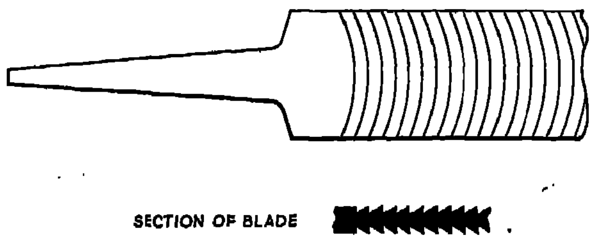


FIG. 6.

Not only must the handle be fitted in axial alignment with the blade, but it should also be firmly fixed so as to embrace the greater part of the tang, otherwise, should the handle come adrift during heavy filing work, serious injury may be caused to the operator.

In addition, to avoid chafing or blistering the hand, the surface of the handle should be smooth, and any roughness should be removed with fine sandpaper.

Once a handle has been securely fitted to a file it should so remain until the file is discarded, for the frequent changing of handles will soon cause looseness with its attendant drawbacks.

Correct Height of Vice

Mention has been made elsewhere in this book of the importance of mounting the vice securely, and it is equally important

for efficient working that the vice should be set at the correct height to suit the operator.

This is usually determined by setting the top of the vice at the height of the operator's elbow-point when his forearm is bent to a right angle.

If the same vice is used by several mechanics it should be set for the tallest, and a low platform is used to enable the shorter to use the vice comfortably; in any case, where the workshop has a stone floor the provision of a wooden platform is an advantage.

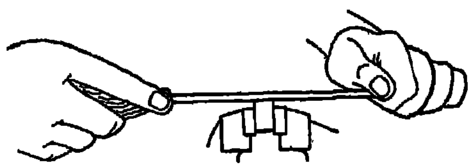


FIG. 7 (A).

Filing

Figs. 7A and 7B show the correct way in which a file should be held for heavy and fine filing respectively. The operator should stand well up to the vice with the feet firmly planted and the legs a little apart, the left foot being advanced in the case of a right-handed man.

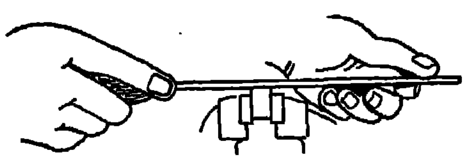


FIG. 7 (B).

At the beginning of the forward stroke the downward pressure of the file is applied by the left hand, in the middle of the stroke by both hands, and towards the end of the stroke by the right hand.

To maintain an even pressure and a truly horizontal position of the file throughout the stroke requires much practice, but these factors are essential for accurate filing.

It should be noted that, as in hacksawing, downward pressure is applied only during the forward stroke and should be relieved on the back stroke to save blunting the file teeth, which are designed to cut only in the forward direction.

Draw-Filing

To impart a fine finish to work which has been filed accurately to shape, a process known as draw-filing is used. Here, the file, held in both hands and at right-angles to the work, is drawn backwards and forwards along the work until the whole surface is made uniform and the desired finish is obtained.

In the initial stage a coarse file may be used, followed by a fine file to remove the previous file marks and form a finely finished surface.

With practice, flat square surfaces can be formed by draw-filing and the tendency to produce a central hollow in the length of the work will be overcome.

Another method of accurately finishing work is that employed by instrument makers; the work is moved backwards and forwards by hand against the teeth of a file held against the bench top or supported in a wooden tray.

In this way a fine accurate finish is obtained which is further enhanced by the final lacquering process.

Holding Work in the Vice

Bench vices are usually fitted with a pair of hardened steel jaws secured to the vice body by countersunk screws, and to hold the work from slipping these jaws are serrated like the face of a file.

To avoid damage to finished work it is customary to use removable clams of soft metal or cardboard, bent to an angle to maintain them in place between the vice jaws.

An alternative method is to have the vice jaws ground to a smooth surface, but this work must be accurately carried out in order to preserve the true apposition of the vice jaws when in place.

After the jaws have been treated in this way, thin card clams only are required to protect the surface of finished work held in the vice.

Cleaning Files

Files sometimes have a tendency to "pin" or become clogged by particles of metal adhering to the teeth, and this is most marked when a new file with fine teeth is used to file steel.

The usual method of removing the metal chips is to brush the file with a file-card, which is a hard stubby wire-brush of wool manufacturer's carding attached to a wooden handle.

At times the metal particles are so firmly adherent that a pointed rod or pricker has to be used for their removal.

When pinning is apt to occur the trouble may be overcome by chalking the surface of the file, and in the case of aluminium and its alloys the application of thin oil or paraffin may be beneficial.

Storage of Files

As files are easily damaged and blunted by ill-treatment or rusting, they should not be stored indiscriminately in a drawer, for the inevitable contact of the files will be highly detrimental to their fine brittle teeth.

A better method is to store the files in racks in such a way that they cannot come into contact with one another, and when necessary thin oil should be applied to the cutting surfaces to prevent rusting.

Hacksaws

The hand hacksaw is largely used in the workshop not only for cutting up material, but also for removing surplus metal prior to finishing parts to size by filing or machining.

The more accurately the sawing is performed, the less will be the labour and material wasted in carrying out the subsequent finishing operations.

To achieve this accuracy of working, it is essential that the saw frame and blade should be suitable for their purpose, and that the correct method of using the saw should be followed. Hacksaw blades are now manufactured with such precision that they can be relied on to cut accurately if properly used.

Hacksaw Frames and Blades

To obtain the best results it is essential that both the frame and the blade should be of good quality. The frame should hold the blade firmly and squarely to prevent it from wandering when cutting.

For general and heavy work the pistol grip is an advantage, for, when it is gripped by the hand, the wrist becomes what is termed cocked or raised and is then in a strong position for operating and controlling the saw, as well as being less liable to fatigue.

The file handle type of grip, on the other hand, is suitable

for lighter and finer work, for, as in the case of the file, there is more delicate control when the hand is in line with the blade.

A saw frame with a handle of this form is shown in Fig. 8, and in this case the blade is tensioned by twisting the handle.

Fig. 9 shows a more elaborate frame with pistol grip and adjustment for accommodating blades of from 8 to 12 inches in length; provision is also made for holding the blade in a position at right-angles to the frame.

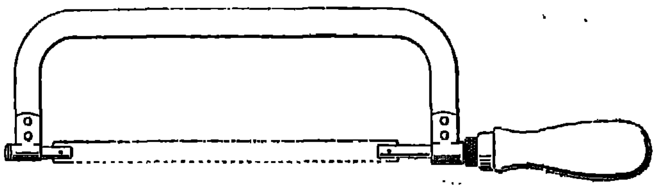


FIG. 8.

Blades for use in these frames can be obtained of either the "all hard" or the "flexible" type. In the former the whole blade is hardened except for a small area round the fixing hole at either end, whilst in the flexible variety only the teeth are hardened.

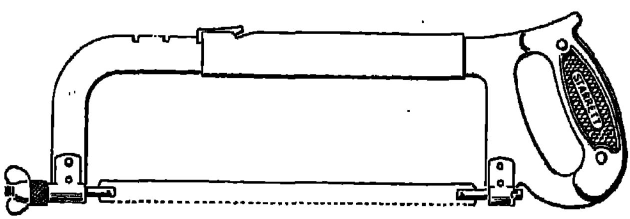


FIG. 9.

Manufacturers recommend the use of blades of varying tooth pitch as set out in the following table and illustrated in Fig. 10.

Regular	14 teeth per in.	For cutting soft steel, cast-iron, bronze and aluminium.
Medium	18 „ „ „	For cutting tool-steel, iron pipe, hard metals and light angle iron.
Fine	24 „ „ „	For cutting brass, copper, drill rod, medium tubing and sheet metal.
Tubing	32 „ „ „	For cutting thin tubing, electrical conduit and thin sheet metals.

In addition to manufacturing the "Eclipse" hacksaw frames and blades, Messrs. James Neill & Co. also make a small saw for light work as illustrated in Fig. 11.

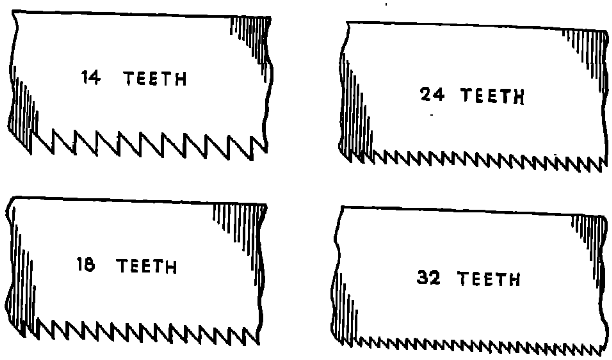


FIG. 10.

The frame, made from spring steel, imparts the necessary tension to the blade, and this simple form of construction also facilitates the changing of the blade.

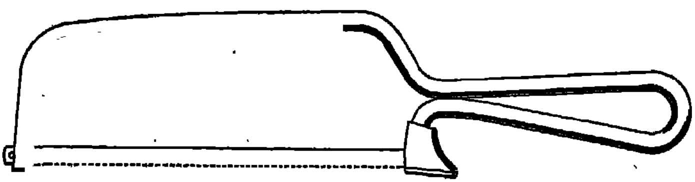


FIG. 11.

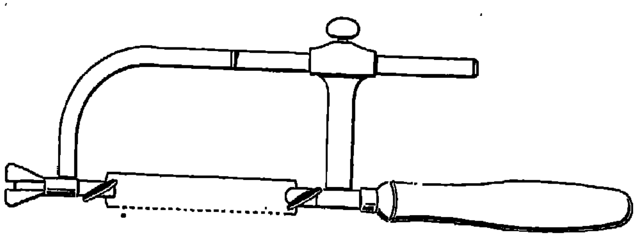


FIG. 12.

The standard form of blade with 32 teeth to the inch is eminently suitable for cutting thin-walled tubing and sheet metal.

The so-called Piercing Saw, shown in Fig. 12, is another

form of small hacksaw used for even finer work than the foregoing. The frame has an adjustable sliding back, and the tension of the blades is controlled either by the inherent spring of the frame or with a thumb nut.

The blades, which are available in several widths, have 36 teeth to the inch and are 5 inches in length.

The " Abrafile " manufactured by Messrs. Abrasive Tools Ltd. is a form of small hacksaw comprising a spring steel frame carrying a saw blade of circular section.

The blades are made in three grades of cut, and, in addition, special links are obtainable to enable the standard blades to be used in the ordinary hacksaw frame.

The saw, which is illustrated in Fig. 13, is well-adapted for cutting curved profiles or for slotting drilled holes where a larger blade will not enter.

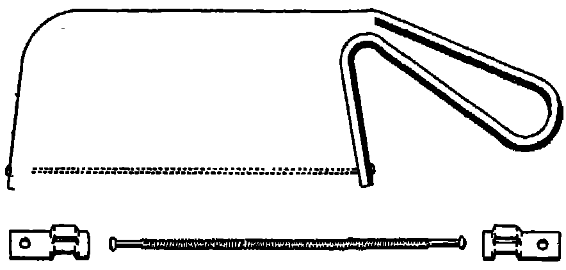


FIG. 13.

Using the Hacksaw

From what has already been written it will be apparent that several varieties of blade will be required for work of different classes, and it is hardly good practice to keep a single hacksaw and use it on all occasions.

As it would be irksome to change the blade each time to suit the work, it is preferable to keep several frames equipped with blades suitable for all ordinary work; in this way both economy of blades and better work will result.

At the outset, a frame with a suitable blade must be selected in accordance with the recommendations already given. For fine work, the small frames and fine-tooth blades that have been described will be found best for the purpose, for here speed of working is usually of lesser importance than accuracy and good finish.

For heavier work a full-size frame should be chosen equipped with a blade of correct tooth pitch and, in this connection, it should be pointed out that it is better to err on the side of using a blade of too fine pitch, for although cutting may be

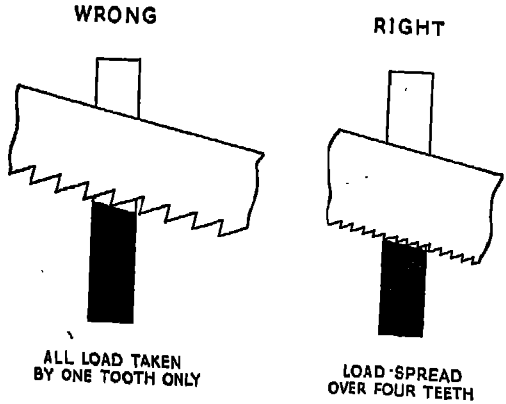


Fig. 14.

slower, the teeth will not be broken as would probably happen with a blade too coarse for its purpose.

The diagrams in Fig. 14 will make clear the effects of using fine and coarse-tooth blades, and it will be seen that when using the latter an undue proportion of the cutting load may fall on a single tooth leading to its fracture, whereas, if several

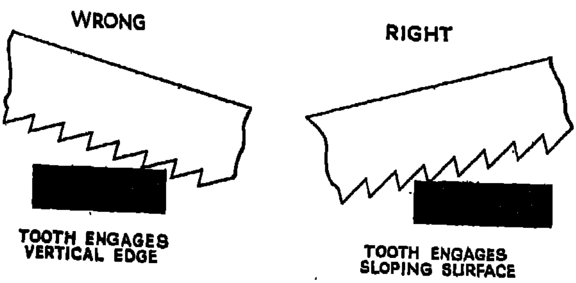


Fig. 15.

of the fine teeth are simultaneously engaged, the tooth loading will be more evenly distributed.

In the same way, as shown in Fig. 15, the saw teeth should not at the outset be engaged with a vertical edge but rather with a sloping surface.

As has been stated, materials and labour will be economized if the hacksawing operation is carried out accurately so as to leave the minimum of metal for removal by the finishing process.

To ensure this, the work should be properly marked-out in the first place. The surface of the work should be coated with marking-out fluid and the dimensional lines scribed on all faces involved during sawing.

In addition, guide-lines should be scribed outside the dimensional lines and at a distance from them a little greater than the thickness of the saw blade, for, from an optical point of view, it is easier to saw midway between two parallel lines than to keep at a fixed distance from one. Moreover, if one line is thrown into shadow by the saw blade the other should remain visible.

Reference to the scribed lines at the back of the work will also ensure that the correct alignment of the cut is being maintained.

The physical action involved in hacksawing is akin to that of filing, and, likewise, slow strokes should be made and relief given on the backward stroke to avoid blunting the teeth.

When hacksawing large surfaces many teeth may be engaged simultaneously with the work, necessitating increased downward pressure to maintain effective cutting and to prevent the saw from merely rubbing the work, but if from time to time the saw is tilted either backwards or forwards, the load will fall on fewer teeth, and the downward pressure may be reduced accordingly.

Hand Hacksawing Machine

As will be seen in Figs. 16 and 17, this device consists of a stand with two vertical pillars on which slide a pair of members carrying the two cross-heads for attachment of the saw frame.

To ensure rigidity the pillars are tied together by a cross-bar.

The base, made of $\frac{3}{8}$ in. steel plate, is provided with a swinging mounting for the attachment of a standard "Yankee" machine vice which can be set at any angle desired.

Though not shown in the general view, the two pillars are provided with clamps, which act as adjustable depth stops by controlling the downward movement of the sliding member and so limiting the depth of cut.

For accuracy of working it is essential that the saw blade

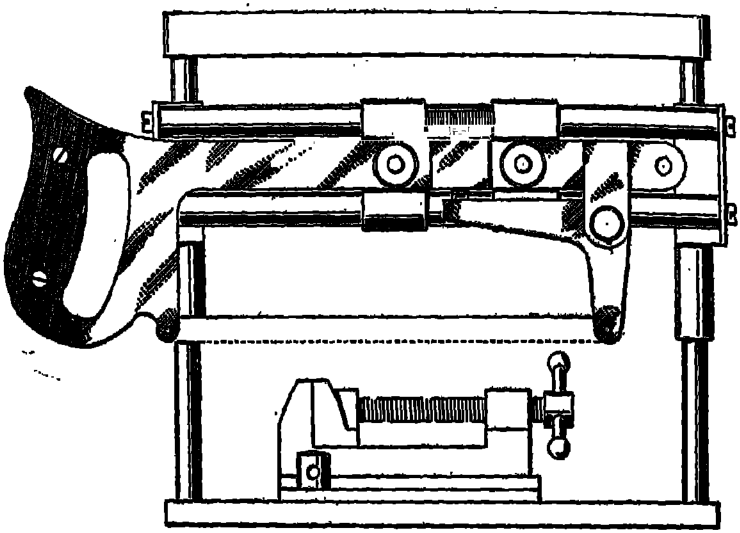


Fig. 16.

should be held truly by the frame, and to ensure this the method shown in the drawing was devised for tensioning the blade.

Power-Driven Hacksaw Machines

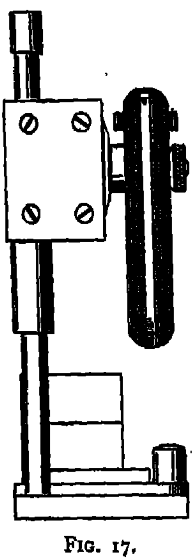


Fig. 17.

If much repetition sawing is undertaken or heavy sections of metal have to be cut, a power-driven hacksaw will be found a great advantage.

Fig. 18 shows a simple but efficient form of this machine in which a single casting, mounted on a pair of legs, carries all the working parts.

The saw frame is carried on guideways, on which it is free to slide to and fro in conformity with the reciprocating motion imparted to it by means of a crankshaft and connecting rod.

The driving pulley, which runs free on the crankshaft, carries a pair of dogs that engage a second pair of dogs on the crankshaft when the clutch lever is actuated.

A counter-balance weight, mounted on an arm attached to the saw frame, provides relief for the blade on the forward or idle stroke.

A prop is fitted to hold the saw clear of the work while adjustments are being made.

The machine shown is not adapted for angular cutting, as the vice cannot be swivelled, but this feature is usually found in the more elaborate machines.

The more expensive hacksawing machines have many further advantages; for example, an oil dashpot controls and slows

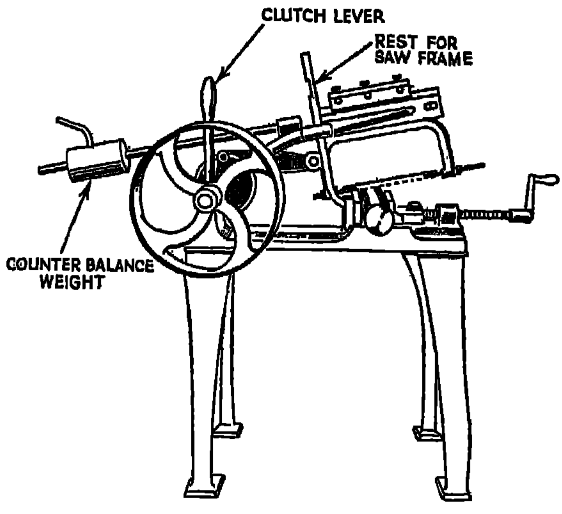


FIG. 18.

the engagement of the saw with the work, thus preventing damage of the saw teeth due to too violent contact.

Another useful accessory, fitted to the larger machines, is a suds pump which keeps the saw blade continuously flooded with cutting fluid.

This fluid collects in a trough immediately below the saw, whence it drains into a reservoir in the base of the machine where, after filtration, it is again ready for circulation by the pump.

Scrapers

Although commercial scrapers are made of tool or alloy steel, these tools can also be obtained fitted with a tip of Tungsten

carbide, but this material is rather brittle when formed to a fine edge and, moreover, it is necessary to use a special hone to obtain the sharpness essential for producing a high finish on the work.

It is the usual practice in the workshop for the mechanic to make his own scrapers from the materials available, and for this purpose Swiss or other good quality files of fine cut are suitable.

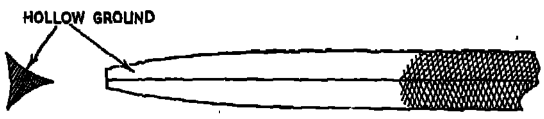


FIG. 19.

Making Scrapers

To make a triangular scraper of the form shown in Fig. 19, an old triangular file is ground on its three sides against the periphery of the grinding wheel. In this way the facets or sides of the blade are formed hollow, and but little honing on an oil-stone will be subsequently required to produce smooth sharp cutting edges.

Re-sharpening also will entail little effort, as the hollow-ground form ensures that only a small amount of metal will require removal by the oil-stone.

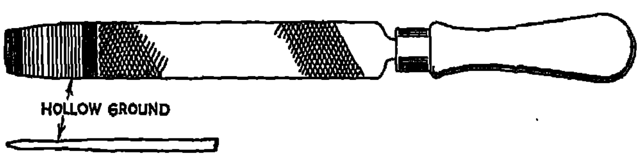


FIG. 20.

In this case, as for all scrapers, it is essential that a large comfortable handle should be fitted to afford proper control of the blade under working conditions.

The flat form of scraper depicted in Fig. 20 is also made from a discarded file of suitable form.

The two sides of the tip are ground slightly hollow on the periphery of the grinding wheel, and the end is formed a little curved to prevent the corners of the blade from digging into the work.

Great care must be taken when grinding not to over-heat the blade, particularly in the later stages of the operation when the thinned edge does not readily carry away the heat engendered. The practice of dipping the tool into water during the course of the grinding process may cause surface cracks to form in the metal, and for this reason it should be avoided.

After being ground to shape, the cutting edges of the scraper are sharpened on a flat carborundum stone to remove the grinding marks, and the final finish is imparted by honing on an oil-stone.

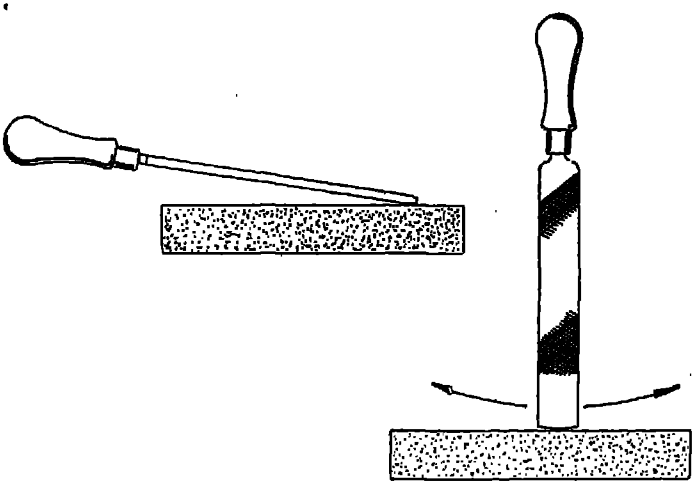


FIG. 21.

Fig. 21 illustrates the methods of hand-stoning commonly used. When stoning the sides of the blade the angle of incidence with the stone should be carefully maintained as in the case of a wood chisel.

The end face is honed by holding the scraper vertically and drawing it backwards and forwards along the stone with a slight rocking motion to conform with the curvature of the tip.

If the scraper is then tried on a smooth piece of mild steel or cast iron it should cut cleanly and with the application of but little pressure, if not or if lines appear on the scraped surface due to irregularities of the cutting edge, the honing must be contined until the proper cutting qualities are obtained.

Using Scrapers

The triangular form of scraper is commonly used for scraping bearing brasses to fit bearing journals.

In this case, the journal is first smeared evenly with a thin coat of marking compound, such as Messrs. Stuart & Sons' Engineers' Marking, and it is then mounted in its brasses and slightly rotated.

On removal of the shaft its points of contact will be clearly indicated on the brasses. These high-spots are removed with a triangular or similar form of scraper, and the process of marking and scraping is continued until satisfactory bedding of the shaft in its bearings is obtained.

The scraper should be kept sharp and must be so held and operated in relation to the work that clean cutting without chatter marks is effected.

The flat scraper, on the other hand, is used for working on and for forming flat surfaces, and in addition it is employed when bedding two flat surfaces together.

When two ground flat surfaces are engaged, as in the case of a machine slide, one of these surfaces should be broken-up, as it is termed, and bedded to the other by hand-scraping.

This results in better mutual working of the surfaces and aids the retention of an oil film between them.

As only small amounts of metal can in the ordinary way be removed by scraping, parts should be accurately filed or machined prior to the final scraping process.

In point of accuracy, the small workshop can equal or even excel the factory which relies on surface grinding for finishing flat surfaces. Although this hand work requires both skill and time, its accuracy is limited only by the degree of perfection of the flat reference surface, which may be either a surface plate or a sheet of plate glass.

When scraping flat surfaces, the surface plate is smeared with marking compound and the work is applied to it with a slight rubbing movement. The high-spots indicated by the transference of the marking are then carefully scraped, and experience will teach when little or much metal requires removal from any particular area of contact.

To maintain free-cutting and an even surface, the direction of scraping should be varied so that the first line of working is crossed at right-angles by the next.

Small areas are scraped to form larger areas of contact,

and the process is continued until the desired uniformity of contact is obtained. As the work proceeds, the amount of marking compound should be reduced, otherwise a false impression of the accuracy of the work will be gained owing to the thickness of the layer of marking.

Finishing Scraped Surfaces

To enhance the appearance of scraped surfaces it is usual to form a pattern on the work by further application of the scraper.

This pattern, which generally consists of two sets of lines of scraper marks crossing at right-angles, gives the work an attractive appearance owing to the unequal reflection of light from the surface.

The individual scraper marks may take the form of crescents or rectangles, and with a little practice these and other patterns can be formed at will.

CHAPTER X

SOLDERING, BRAZING AND HARDENING EQUIPMENT

General Equipment. Coal Gas Appliances. Self-Blowing Gas Blowpipe. Air-Blown Gas Blowpipe. Air Supply for Blowpipes. Petrol and Paraffin Blowlamps. Oxy-Acetylene Welding and Brazing. Oxy-Acetylene Equipment. Acetylene Gas Cylinders. The Blowpipe. Regulators. Air-Acetylene Apparatus. The Brazing Hearth. Hardening Furnaces. Soft Soldering. Fluxes. Solder-Flux Combinations. Low Melting-Point Solders. Soldering Irons. Sweating. Brazing. Silver Soldering or Hard Soldering. Hardening and Tempering. Case-Hardening. Closed-Box Method. Molten-Bath Method. Open-Hearth Method. Case-Hardening Steels.

General Equipment

BEFORE describing the technique of soldering, brazing, and the heat treatment of metals, the equipment required for these operations will be considered.

For the production of moderate temperatures such as are required for soft soldering, a Bunsen burner or gas ring, a small blowlamp, or an ordinary Primus stove will serve to heat the soldering iron; and for heating the work prior to the application of the soldering iron, or for sweating components together, a blowlamp or a self-blowing gas blowpipe may be used.

On the other hand, in the wireless and many other industries the electrically-heated soldering iron is now used almost exclusively.

To produce the higher temperature necessary for brazing, a powerful blowlamp may be used, but where coal gas is available a gas blowpipe will usually be found more convenient, and the air supply necessary for its operation may be provided either by a foot-bellows or by a power-driven blower.

In addition to using acetylene gas with a suitable type of Bunsen burner, it is also possible to utilize it for brazing purposes provided that special equipment is employed.

The combustion of acetylene gas with air or pure oxygen in a suitable burner produces an intensely hot flame suitable for brazing, welding and cutting metals.

The British Oxygen Co. manufacture apparatus specially designed for use in conjunction with these processes, and for brazing a special hard bronze alloy is supplied.

This method of welding and brazing is now largely used for manufacturing purposes in the production of fabricated components and structures, in addition to the repair work for which it was originally designed.

Where coal gas for operating burners and blowpipes is not available Calor gas may be used with advantage, and as it

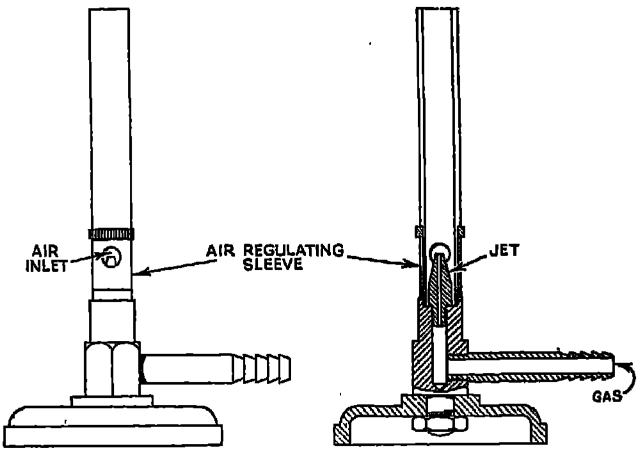


FIG. 1.

is contained in cylinders under pressure, it will operate high-pressure blow torches for brazing without the use of a supplementary air blast.

In addition, Calor gas may, if desired, be used with suitable types of Bunsen burners and air blast blowpipes.

As some of these heating appliances can be readily made in the workshop, some details of their construction may be found useful.

Coal Gas Appliances

Fig. 1 shows a typical Bunsen burner in which the gas is mixed with air at the base of the vertical tube and burns at the top of the tube, either with a clear blue or a yellow luminous

flame according to the amount of air admitted by the air regulating sleeve.

As will be seen in the sectional drawing, the vertical tube is provided with a cross-drilled hole corresponding with holes in the air regulating sleeve, and so by turning the latter the relative proportions of gas and air entering the vertical tube are adjusted.

Some burners have in addition a screw-down needle valve to adjust the quantity of gas issuing from the jet, and in some instances a diffuser is fitted to the top of the vertical tube to spread the flame and render it more suitable for heating a soldering iron, but when a diffuser is used, a wire gauze should be fitted to the flame tube to prevent the burner from lighting back when weak gas to air mixtures are used.

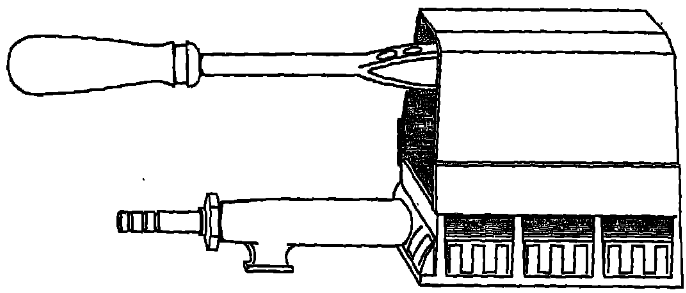


FIG. 2.

Fig. 2 shows the Fletcher Russell Tinman's Stove, which is virtually a standard gas-ring burner, fitted with a cast-iron hood open at one end and provided with a rest to support the soldering iron.

Self-Blowing Gas Blowpipe

A useful form of self-blowing gas blowpipe for either soft- or light hard-soldering work is shown in Fig. 3.

As will be seen from the illustration the device has two jets; the central jet provides a high velocity stream of gas which causes the gas issuing from the main jet to be deflected to form a sharply defined narrow flame of great intensity.

Although this type of blowpipe is sensitive to variations of gas pressure, some measure of adjustment is provided to meet this and to vary the size of the flame, but in some instances

it may be necessary to alter the size of the jets in accordance with the gas pressure.

The essential simplicity of the device renders it easily constructed in the workshop.

Air-Blown Gas Blowpipe

Where a supply of town gas is available the best heating apparatus for brazing is perhaps an air-blown gas blowpipe of the types shown in Figs. 4 and 5.

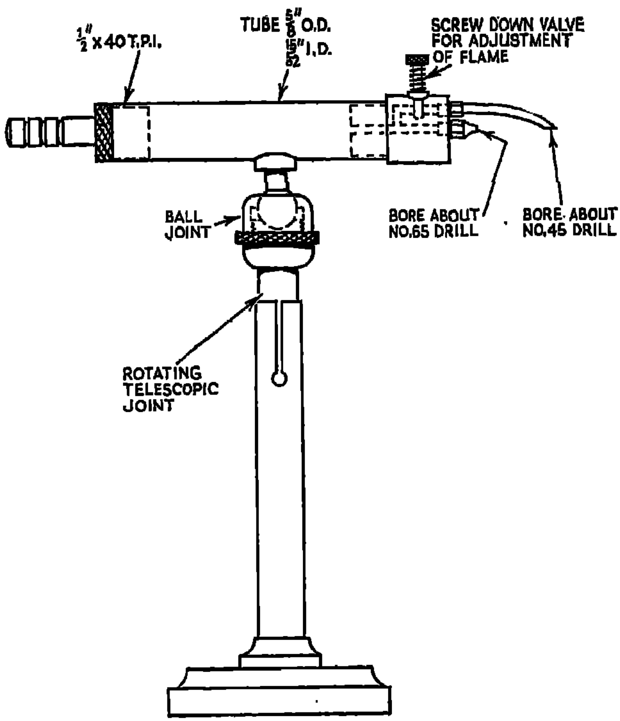


FIG. 3.

The former illustration depicts a laboratory pattern blowpipe, commonly used by glassworkers, dentists and jewellers, which admits of fine adjustment of the intensity and size of the flame and also allows the position of the device to be accurately set.

The heavy cast-iron base affords good stability, but screw holes are provided for positive fixation to the bench should this be desired.

In Fig. 5 is shown the type of blowpipe generally used by copper-smiths, cycle repairers and mechanics. This device operates on the same principle as the previous example, but

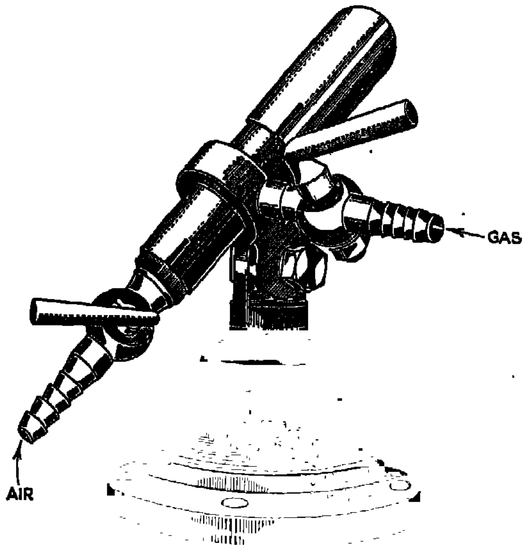


FIG. 4.

here the air supply remains constant and the gas supply alone is regulated by means of a trigger-operated gas valve. This valve is, in addition, furnished with an adjusting screw to regulate the minimum admission of gas, with a view to preventing the extinction of the flame when the blowpipe is not in operation.

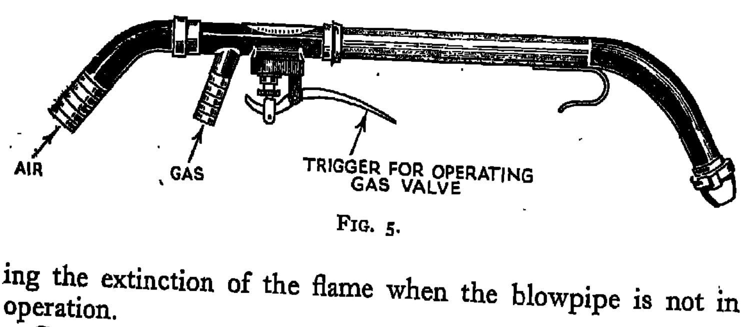


FIG. 5.

Gas blowlamps have the outstanding advantage that, unlike blowlamps, they seldom require cleaning, and apart from

mechanical damage and misuse, they will continue to operate indefinitely, but on the other hand, these blowpipes require an external source of pressure air supply for their operation.

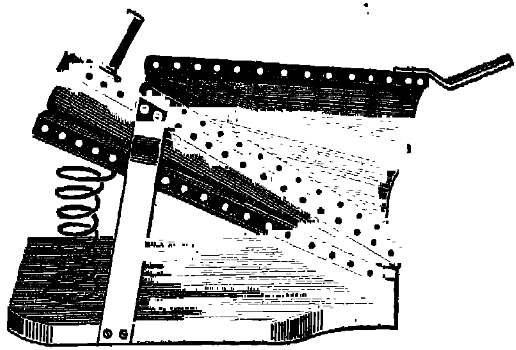


FIG. 6.

Air Supply for Blowpipes

This air supply may be provided either by a foot-operated bellows, as illustrated in Fig. 6, or a mechanically driven

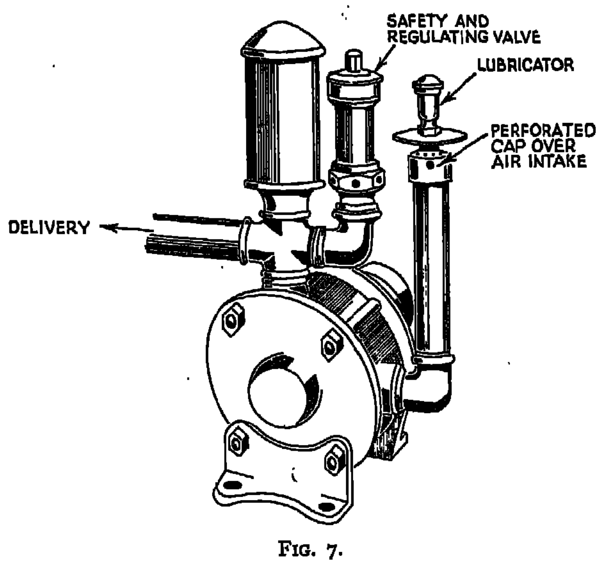


FIG. 7.

centrifugal blower of the type shown in Figs. 7 and 8 may be employed.

If brazing is only occasionally undertaken, a double-acting

foot bellows of good quality will probably suffice, and the type illustrated will be found to give a steady air supply with the minimum of effort.

If, however, more extensive brazing work is carried out, a power-driven source of air supply is preferable, and for this purpose a rotary type of blower as illustrated is usually employed.

In this machine the rotor carries hinged vanes which under the influence of centrifugal force are pressed against the inner wall of the blower casing, and as the vanes revolve they draw in air through the intake and expel it under pressure from the delivery side of the blower.

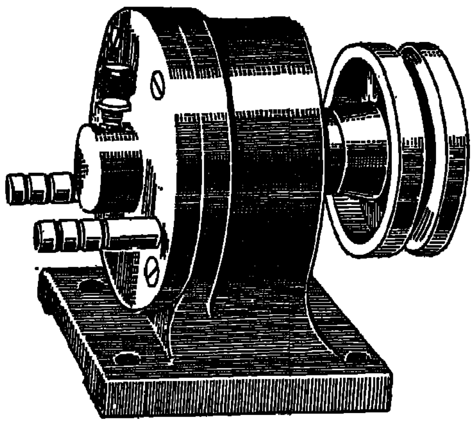


FIG. 8.

Fixed to the delivery side of the machine is a combined safety and regulating valve and also a small air chamber to steady the flow of air.

It should be emphasized that in no sense are these blowers high-pressure pumps, for they are designed solely to deliver relatively large quantities of air at low pressure for the purpose of operating a small forge or a gas blowpipe.

In view of the frictional losses necessarily arising from this form of vane design, it is necessary to allow regular quantities of oil to mix with the incoming air to ensure that the vanes are adequately lubricated; this will in time cause an accumulation of oil which will tend to reach the blowpipe itself unless an oil separator is interposed in the air line.

This separator usually takes the form of a large drum, which, by reducing the velocity of the air stream, allows the oil particles to settle at the lowest point and so facilitates regular removal of the accumulated oil.

The smaller type of centrifugal blower illustrated is suitable for intermittent work and is largely used by dentists and jewellers whose silver soldering operations are of relatively short duration, for in this machine the less elaborate lubrication system is not adapted for prolonged or continuous running.

Petrol and Paraffin Blowlamps

The light blowlamp illustrated in Fig. 9 holds some two-fifths of a pint of benzoline or petrol and will burn for about an

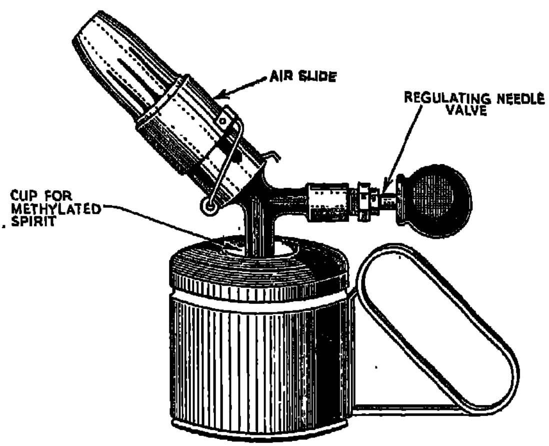


FIG. 9.

hour with a single filling. The intensity of the flame is regulated by the screw-down needle valve which is seen projecting from the base of the burner.

In operation, the wick contained in the vertical tube supporting the burner assembly draws the fuel into the base of the burner below the needle valve, and, when the burner is heated by the methylated spirit ignited in the depression at the top of the reservoir, the fuel is vaporized and issues in this form from the burner jet when the needle valve is opened.

The heat generated by the combustion of this vaporized

fuel when the lamp is in operation is then sufficient to maintain continuous vaporization.

As will be apparent, a sleeve is fitted to the combustion tube as in the case of the Bunsen burner, in order to afford some control of the intensity of the flame.

As the heat generated by a lamp of this type is sufficient for small brazing operations, care must be exercised when it is used for soldering thin sheet metal.

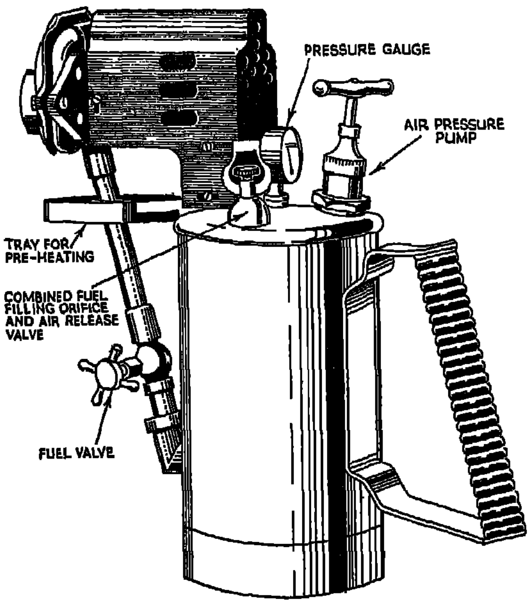


FIG. 10.

A more powerful blowlamp designed for brazing operations is illustrated in Fig. 10. Although the working principle is the same as that of the smaller lamp already described, the combustion of the paraffin fuel is much more rapid, and to maintain the supply of fuel to the burner a hand pump is fitted to provide the necessary air pressure.

The fuel supply is also controlled by a fuel valve fitted to the pipe leading from the container to the vaporizer.

In a lamp of this type the normal working pressure of 20 to 30 lb. per square inch will produce a large fierce flame, but if a flame of less intensity is desired the air pressure may

be reduced and the fuel supply restricted by operating the fuel valve; however, if the size of the flame is unduly cut down vaporization will be incomplete and a yellow flame will result.

The container of the lamp depicted holds five pints of fuel, which is sufficient for three hours working at full heat.

Oxy-Acetylene Welding and Brazing

The use of oxy-acetylene equipment has now become almost universal for many of the operations mentioned in this chapter, and its installation, even in the small workshop, may well be considered on the score of its wide range of utility and undoubted efficiency.

Although a short description of oxy-acetylene and air-acetylene apparatus is given as a guide to intending users, it is not possible in the space here available to describe the use and application of this equipment, and moreover, it would be more profitable for those embarking on this work to study the handbook published by the British Oxygen Co. in which the subject is dealt with in detail and with great clarity; furthermore, a practical knowledge of the processes involved can be most readily acquired from instruction by a skilled operator.

Oxy-Acetylene Equipment

A comprehensive set of equipment is shown in Fig. 11, and the units of which it is composed will be clearly seen in the illustration.

Both gas cylinders are provided with gas regulators to ensure that the gas supplied to the burner or blowpipe is at a constant pressure, and in accordance with the requirements of the nozzle used.

In addition to the equipment shown, the following items will be required for welding and brazing: cylinder valve keys, spanners to adjust the cylinder regulators and the burner, a suitable spark lighter, and protective goggles. Furthermore, a supply of welding rods and fluxes suitable for the work undertaken will be necessary.

Acetylene Gas Cylinders

The cylinder is a drawn steel container fitted with an outlet valve at its upper end, and a safety plug is contained in the

lower end which is formed to maintain the cylinder in an upright position when in use. The cylinder is filled with porous material to prevent sudden decomposition in the

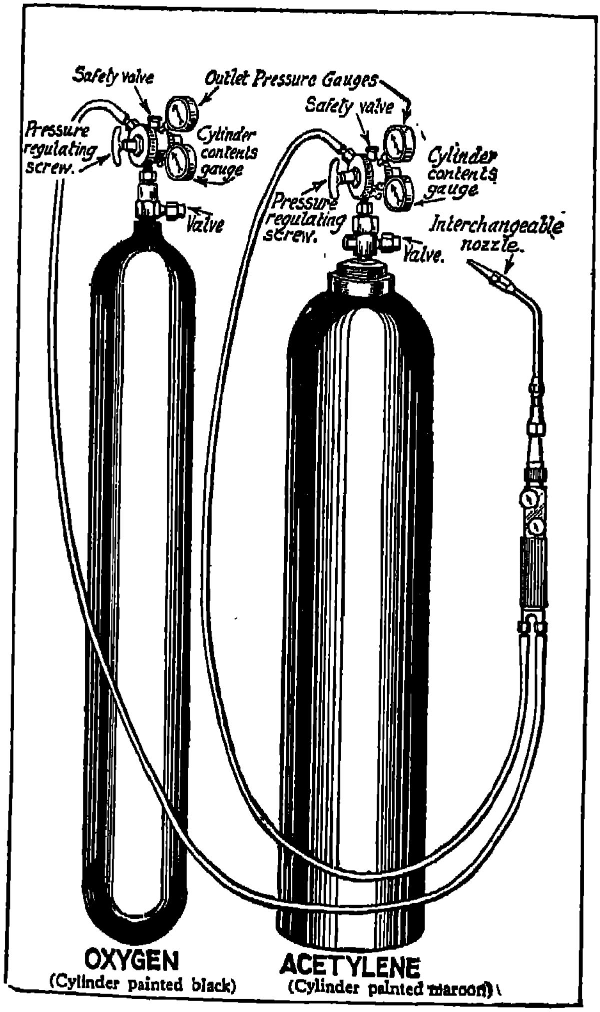


FIG. 11.

event of local heating, and the pores of the filling substance are saturated with acetone to dissolve the acetylene gas.

It is important that, when discharging, the cylinder should be kept in an upright position.

The Blowpipe

Fig. 12 shows a partly sectioned view of this piece of apparatus. The two control valves are used to adjust the flow of the gases, which are mixed in the correct proportion in a chambered recess designed to prevent the flash-back of the flame.

The mixed gases are allowed to expand in a conical passage, whence they pass through a neck pipe to the nozzle where they are burned.

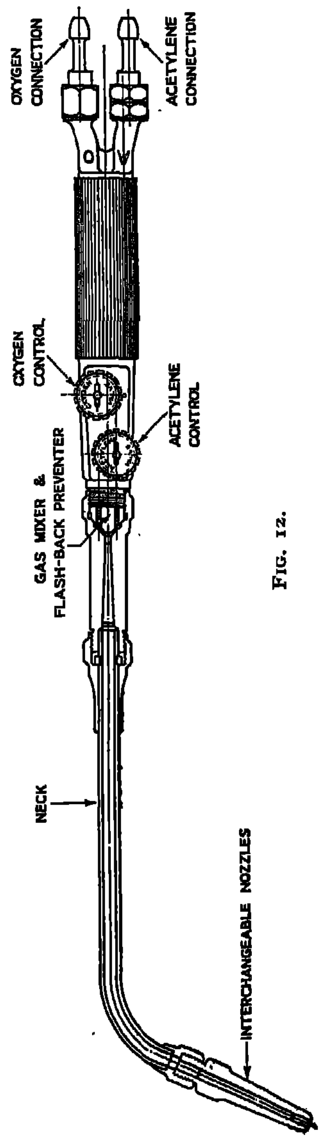


FIG. 12.

Regulators

A standard type of single-stage regulator is shown in the sectional drawing in Fig. 13.

This device comprises three main components: a pressure spring, a diaphragm, and a valve. These are so arranged that the spring opens the valve and allows the incoming gas to act on the diaphragm which as the pressure rises closes the valve. The pressure required is set by the pressure adjusting screw.

The single-stage regulator, when used with high pressure oxygen cylinders, requires repeated adjustment to maintain a constant output pressure as the pressure of the gas within the cylinder falls. The use of a two-stage regulator overcomes this difficulty, and an even output pressure is maintained throughout the period of discharge of the gas cylinder.

Air-Acetylene Apparatus

This is used for lead-burning, soldering and brazing, and is so designed that the current of acetylene from a cylinder of the compressed gas is mixed with air by the injector action of a suitable blowpipe.

Three forms of blowpipes made by the British Oxygen Co.

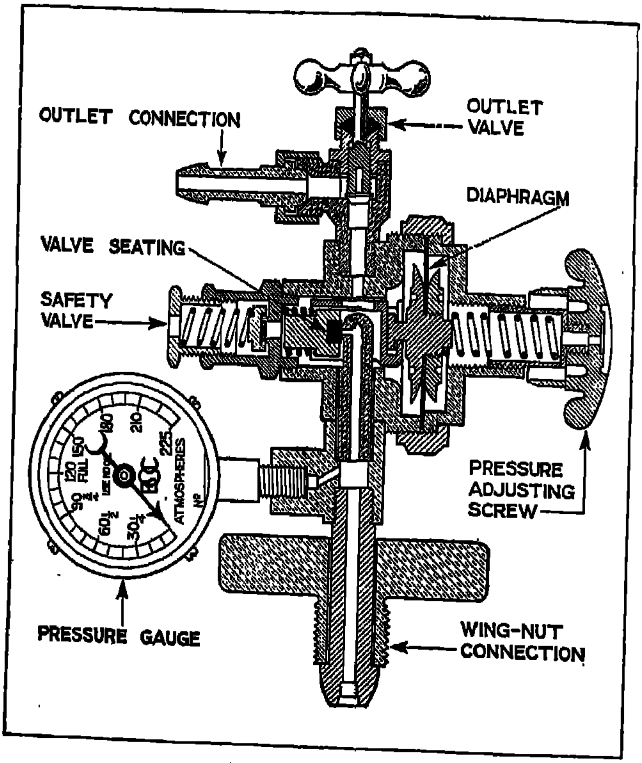


FIG. 13.

are shown in Fig. 14, and although the gas supply can be controlled by the fine adjustment valve fitted to the cylinder, a standard type of regulator is preferable.

The Brazing Hearth

Owing to the heat produced during brazing operations some form of protective hearth is necessary for all but the smallest work.

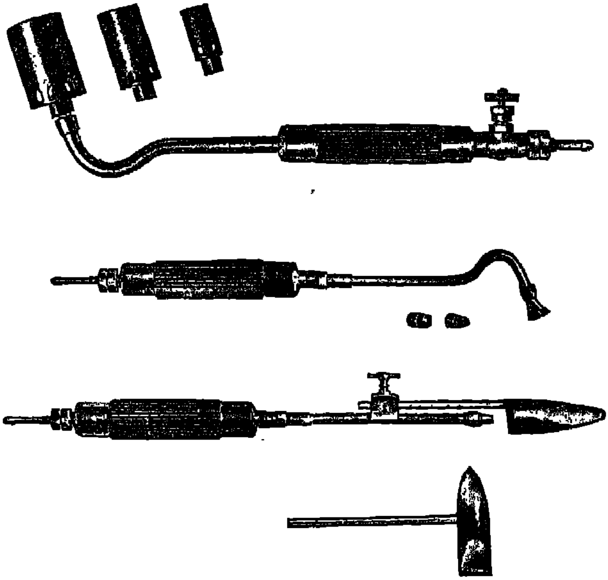


FIG. 14.

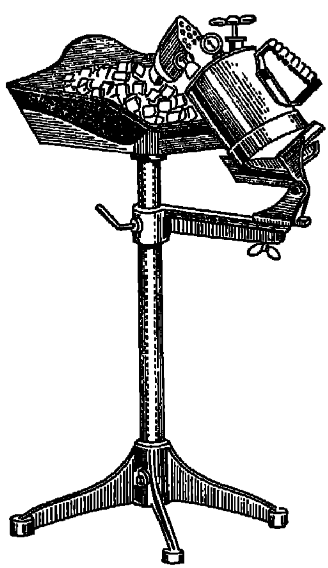


FIG. 15.

In its simplest form this hearth may consist merely of two large firebricks to form the floor and the back of the structure, and additional pieces of firebrick or asbestos cubes may be built round the work to concentrate and retain the heat.

A more elaborate brazing hearth designed for this special purpose is illustrated in Fig. 15.

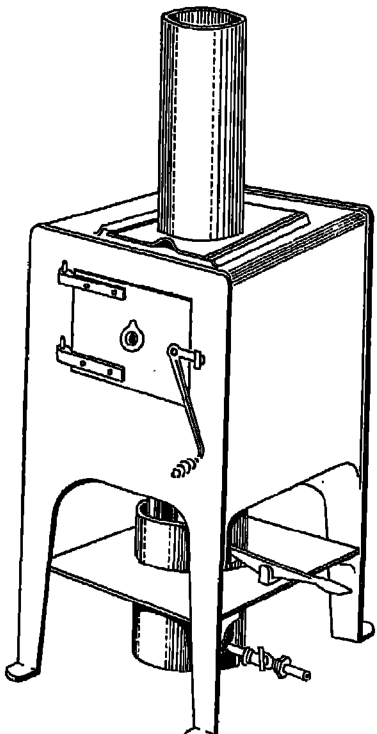


FIG. 16.

This contrivance consists of a deep cast-iron tray mounted on a tubular column which is furnished with a swinging bracket and an adjustable clamp to hold the blowlamp.

This lamp carrier is a useful fitting as it frees the hands for dealing with the work.

The floor and back of the tray are lined with firebrick, and firebrick or asbestos cubes are used as packing material.

Hardening Furnaces

Although processes such as case-hardening can be carried out in an open hearth, better results will be obtained by using some form of furnace.

The type shown in Fig. 16 is gas-operated, and, as a natural air draught is provided, a mechanical blower is not required.

This furnace will attain a temperature of 900°C. and can be brought to its maximum temperature in fifteen minutes.

The provision of a door at both ends of the furnace allows long work to be accommodated if required.

The size of the heating chamber in this model is 6in. wide, 4 in. high and 8 in. deep.

Similar types of furnaces are made equipped for electrical heating, and these have the advantage that they are free from fumes and require no ventilation.

Soft Soldering

This is the process of joining metals by means of a film of a low melting-point metallic alloy assisted by a suitable chemical flux.

Although some metals are more difficult to solder than others, the more recalcitrant are becoming amenable to the process as the necessary solders and fluxes are chemically *investigated.*

As opposed to brazing and silver or hard soldering, soft soldering is carried out at relatively low temperatures, and the solders used mostly become fluid at temperatures of from 150° to 300°C., depending on the nature and proportions of the constituents used.

The basic elements of soldering alloys are lead and tin, and when other metals such as antimony, copper, and cadmium are added the melting-point temperatures are modified as shown in the table on page 187.

The cadmium alloy solders, which appear at the foot of the table, have the advantage of imparting an increased tensile strength to the joint and are thus satisfactory for use where normal lead-tin solders would fail.

Fluxes

As in the case of brazing, it is essential to use a flux to inhibit

the formation of metallic oxides which would prevent the proper adherence of the solder.

The fluxes used for soldering have both a mechanical and a chemical action, and the most widely used are zinc chloride, ammonium chloride and resin. The latter is used for soldering joints in electrical apparatus where it is essential to avoid corrosion resulting from chemical action.

Solder-Flux Combinations

Formerly, it was the practice to apply the flux separately to the work, but solders are now produced in tubular form with resin and other fluxes contained in the interior.

One of the most successful of these products is that manufactured by Multicore Solders Ltd.; this solder has several cores of resinous material specially treated to increase its fluxing properties.

A further advance has recently been made in the manufacture of solder-flux combinations by Messrs. Fry's Metal Foundries Ltd., who have produced solder paints and pastes which can be readily painted or spread on the surfaces to be joined.

These preparations can be used either with a soldering iron in the usual way, or may be employed for sweating operations by direct heating.

Low Melting-Point Solders

Where it is undesirable to apply undue heat to the work, a low melting-point solder with a bismuth base may be used. If the proportions of the ingredients are: bismuth 50 per cent., tin 13 per cent., lead 27 per cent., and cadmium 10 per cent., the resulting alloy will have a melting-point of 70°C., but will be unreliable under many conditions commonly encountered. The melting-point of this solder can be increased to 95°C. if the cadmium is omitted and the tin and lead proportions are raised to 19 per cent. and 31 per cent. respectively.

These low melting-point solders may in some instances be used with advantage, especially where there is a danger of damaging highly-finished work.

Normal zinc chloride fluxes or those of equivalent type should be used with bismuth-base solders, but resinous fluxes are unsuitable as their melting-point is usually higher than that of the solder itself.

Soldering Irons

The two types of soldering irons in common use are illustrated in Fig. 17, but in addition to these forms a pencil-shaped bit is largely used for soldering small connections in electrical apparatus.

As has been mentioned, the electrically heated soldering iron is now widely used in industry. These irons are so constructed that rapid initial heating is effected, but as the temperature rises the current is automatically reduced by the increased resistance of the windings, and a constant temperature is maintained which is adequate for soldering but insufficient to remove the tinning from the iron.

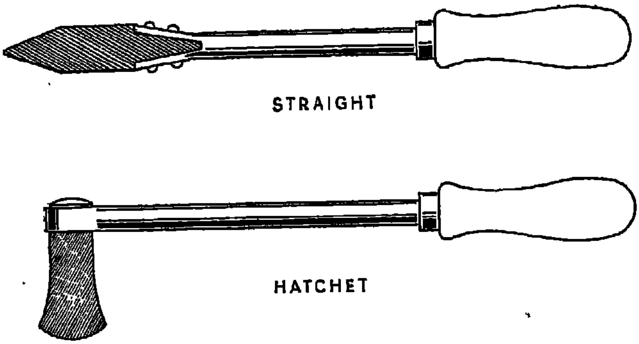


FIG. 17.

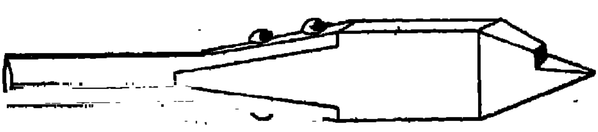


FIG. 18.

Prior to using the soldering iron its tip must be coated with solder, or tinned as it is termed. This is effected by cleaning the tip of the heated iron with an old file, or by rubbing it on a block of bath-brick; the tip is then dipped into the flux and the solder stick is applied until all the sides of the iron's tip are coated with solder.

In order to retain a sufficiency of molten solder on the iron some workers form a notch at the point as shown in Fig. 18.

When soldering pewter and the special lead-tin alloy used for the manufacture of organ pipes a wrought-iron bit is used.

This soldering iron is never allowed to make actual contact with the work, but the heat is transferred from the iron to the joint by the bead of solder which the operator skilfully maintains between the bit and the material on which he is working.

Sweating

This is the process of applying direct heat to join components by means of an interposed layer of solder.

Here, the clean joint surfaces, after they have been coated with a suitable soldering compound, are secured in apposition and heat is applied to the work until the solder melts within the joint. Before the introduction of soldering paints and pastes, a layer of tin-foil was commonly used when sweating together small flat components.

Brazing

This is the process of joining together metal components by means of molten brass or similar metallic alloys.

As in the case of soldering, the molten metal will not adhere to the components unless they are clean and free from substances such as oil, which under heat become oxidized and form a resistant film on the work; even if the surface of the metal is clean the flame itself may cause the formation of metallic oxides unless a flux such as borax is employed.

This fluxing substance liquifies under the influence of the heat applied, and spreads over the surface of the work to form a protective layer, which acts as both a mechanical and a chemical de-oxidizing agent, by preventing the formation of oxides and at the same time chemically reducing any oxides that may be present.

Brass suitable for brazing may be obtained in various forms and qualities appropriate for the class of work undertaken. Brazing strip some $\frac{1}{16}$ in. thick and $\frac{1}{4}$ in. wide is perhaps the most generally useful variety, but the brass can also be obtained as Spelter in the form of fine filings, which when mixed with powdered borax and water to form a paste is applied to the work prior to heating.

If the parts fit together closely it should not be necessary

TABLE OF SOLDERING ALLOYS

Tin per cent.	Lead per cent.	Antimony per cent.	Copper per cent.	Cadmium per cent.	Melting point Deg. C.	Complete solidification point deg. C.
63	37	—	—	—	240	180
50	90	·12	·08	—	215	185
5	95	—	—	—	315	300
10—20	90—80	—	—	—	305—285	260—180
15—35	85—65	—	—	—	295—255	185
45	55	—	—	—	240—237·5	180
37·5	60	2·5	—	—	190	180
95	5	—	—	—	240	230
23	68	—	—	9	235	145
95	—	5	—	—	240	230
50	32	—	—	18	145	145

BISMUTH SOLDERS

Tin per cent.	Lead per cent.	Bismuth per cent.		Cadmium per cent.	Melting point Deg. C.	Solidification point deg. C.
19	31	50	—	—	95	95
13	27	50	—	10	70	70

CADMIUM SOLDERS

Cadmium per cent.	Silver per cent.	Zinc per cent.			Melting Point deg. C.	Solidification point deg. C.
95	5	—	—	—	400	335
50	—	50	—	—	325	265
82·5	—	17·5	—	—	265	265

to add brass during the brazing process, but if this is required brazing strip should be used for the purpose.

The desirability of making all parts a close fit prior to brazing should be emphasized, for brass in the molten state in the presence of a flux is susceptible to capillary action, and will find its way between surfaces which are in contact under moderate pressure, such as the joints of a bicycle frame. The brazing alloy must not, however, be expected to act as a filler as the strength of joints formed in this way is greatly reduced.

Silver Soldering or Hard Soldering

This process is similar to brazing except that a silver instead of a brass alloy is used for uniting components, and as a rather lower temperature is used, its application to brass parts such as sheets and tubes is facilitated.

One of the most successful silver solders is Easy-Flo which is manufactured by Messrs. Johnson Matthey Ltd.; this alloy runs freely at a low red heat and has a high tensile strength. The makers produce a special flux which is clean in use, and after soldering can be readily removed by washing in hot water. Messrs. Johnson Matthey have issued an instruction booklet to which reference should be made for a description of the technique employed when using their products.

Hardening and Tempering

These terms are applied to the heat-treatment of tools, springs and other components made of high-carbon steel, which when brought to a red heat will harden on quenching in water or oil.

This treatment has the effect of hardening the steel throughout its bulk, and in this state it is usually too brittle for useful service.

It may therefore be necessary to reduce this hardness and brittleness by a further process of heat-treatment known as tempering; this is done by reheating the work to a temperature specified by the manufacturers of the steel.

In commercial practice this process is carried out by exact methods, and a pyrometer is used to measure the temperature of the bath of sand, lead or salt in which the steel is treated after the hardening operation.

In the small workshop, on the other hand, this costly equipment and elaborate procedure is not required, for, after hardening, the surface of the steel is polished with emery cloth and the temperature to which the work is raised is estimated by observing the successive changes of colour, due to oxide formation, which occur during reheating.

The following table shows the approximate temperatures, indicated by the colours produced on reheating, which are appropriate for tempering tools and other articles, but it should be borne in mind that the resulting temper depends in some degree on the time occupied in heating the work.

Temperature Degrees C.	Colour	Article
220 and below	Bright	—
220	Pale Yellow	Surgical knives.
230	Pale Straw	Scrapers.
245	Middle Straw	Shaper & Planer Tools, Milling Cutters.
260	Dark Straw	Chasers, Taps & Dies, Drills & Turning Tools
280	Purple	Chipping Chisels.
300	Blue	Springs, Screw Drivers, Wood Chisels.

Prior to tempering tool steel, its hardness should be tested with a file, and if found deficient in this respect it should be reheated to a higher temperature and again quenched; usually heating to a bright cherry red is sufficient and care must be taken not to overheat the steel and thus impair its hardening properties.

When tool steel is quenched in oil the resulting state of temper will usually be equal to that obtained by tempering to a dark straw after hardening. This single process of heat-treatment may at times be used to facilitate the making of small springs and other delicate parts.

Case-Hardening

Where, to resist wear, parts have to be made of hardened steel, the use of tool steel hardened throughout would afford but little tensile strength or ability to withstand stress or shock, but on the other hand, by hardening only the surface of the part, its initial strength is retained and the properties of the underlying steel are unimpaired.

The process whereby this is effected is termed case-hardening, and the thickness of the hardened surface layer can be made to accord with the duty required of the component.

Moreover, in the latter case inexpensive and easily machined steels can be used, and the parts can be ground true to size after being case-hardened.

The basic principle of case-hardening depends on a chemical reaction, which causes the surface layers of the steel to absorb an additional amount of carbon and so become akin to tool steel. This is effected by heating the steel to a suitable temperature whilst in contact with a substance having an absorbable carbon content, with the result that a surface layer of high-carbon steel is formed which can be readily hardened by heating to a red-heat and quenching in water.

Closed-Box Method

In practice, parts which are to be case-hardened by this method are packed in iron or steel boxes filled with bone-dust, leather clippings, or some form of animal charcoal, to which a catalyst such as Barium chloride is sometimes added to hasten the process. After filling, the covers of the boxes are luted with fireclay, and the containers are heated in a muffle furnace for a period of time which varies according to the quality of the steel and the depth of case required. The boxes are then removed from the muffle, and the parts, after they have been freed from the hardening compound, are reheated to the correct temperature and then quenched in water.

For case-hardening small parts the practice of the gunsmith may well be followed; in this trade, in former times, gun and rifle parts were largely made of high-grade iron case-hardened to resist wear and corrosion.

Bone-dust obtained from the button-making industry is commonly employed as the source of carbon, but prior to use it should be parched to expel moisture by heating at a moderate

temperature until in appearance it resembles ground coffee. The parts are packed with bone-dust in a cast-iron box which is maintained at a temperature aptly described as worm-red, or cherry red, in a bright fire for a period of from one to one and a half hours. The contents of the box are then tipped into a bucket of cold water.

Parts so treated have a beautiful colour-mottled appearance, and owing to the absence of exposure to air the high surface finish is maintained undamaged.

Suitable hardening boxes can be made by attaching a long tubular handle to articles such as cast-iron pistons or electrical iron-clad switch or junction boxes.

Should there be any difficulty in estimating the depth of the case-hardening, test rods made of the same material as the components under treatment should be inserted through holes in the lid of the hardening box. At intervals a rod is withdrawn and, after quenching, it is bent to and fro until fracture takes place; inspection with a lens will then clearly reveal the thickness of the outer layer of hardened steel.

A length of steel tubing fitted with suitable end plugs will make an efficient container for case-hardening slender parts.

When a cyanide compound such as Antol is used for case-hardening by the closed-box method, the makers, Messrs. Pidgen Bros. Ltd., recommend that it should be mixed with powdered wood charcoal in the proportion of one part of the compound to six parts of charcoal.

When this mixture is used instead of bone-dust or leather, the time required for the case-hardening operation is reduced to approximately one-third.

Molten-Bath Method

This process, which is widely used in industry owing to its rapidity and general convenience, consists in immersing the articles to be treated in a molten cyanide compound such as Antol, which melts at a low red heat and is fully active at 900°C. or approximately cherry red; ten minutes immersion is usually sufficient to produce a light case.

Articles case-hardened by this method are free from scale and the surface has an even silvery appearance.

The furnace used for cyanide hardening may be of simple construction consisting of a steel casing lined with firebrick, and having a flanged steel pot suspended from the top plate

of the casing. On the other hand, the more elaborate furnace illustrated in Fig. 16 is suitable for this work.

When batches of small parts are treated, the use of a perforated container will facilitate the work of immersion and removal of the components.

As in the case of box hardening, the molten-bath process can be carried out efficiently with quite simple equipment, for all that is required is a cast-iron or steel pot that can be lowered into a coke stove; or even a bright coal fire can be used provided that the contents of the pot are maintained at a bright red heat.

As these cyanide compounds are highly poisonous, care should be taken when they are used, and the manufacturers' instructions should be closely followed.

Open-Hearth Method

This process is quite satisfactory for the treatment of parts where only a small depth of hardness is required and finish grinding is not employed.

The work is heated to cherry red on a brazing hearth and the surface is sprinkled with Antol or a similar compound; after the heat has been maintained for a minute or more, the part is allowed to cool to a dark cherry red and is then quenched in cold water.

The depth of hardening may be increased by continuing the process of heating and sprinkling with the compound, prior to quenching.

Case-Hardening Steels

Whilst ordinary mild steel can be case-hardened the results are somewhat uncertain owing to their varying carbon content, for mild steel usually contains some 0·3 per cent. of carbon, whereas a carbon content of 0·2 per cent. is the maximum allowable for satisfactory results.

Where the carbon content of the steel is excessive, there is a danger of the case-hardening process extending to the interior of the part and thus causing brittleness of the core.

Three classes of steel are commonly used for case-hardening: special low-carbon steels such as Messrs. Flather's Ubas steel; Nickel case-hardening steels with a nickel content of from 3 per cent. to 5 per cent.; and Nickel-chrome steels.

CHAPTER XI

SPRAY PAINTING

Its Use and Advantages. Injector Type Spray Gun. Gravity Feed Spray Gun. Air Supply System. The Compressor. The Primary Air Receiver. Non-Return Valve. Main Air Receiver. Piping. Hose. Paint. Technique.

Its Use and Advantages

SPRAY painting has now been adopted by most manufacturing firms as being the most rapid and efficient method of finishing their products, and the technique has become so highly developed that there is hardly any pigment that cannot be applied by this means.

Apart from the rapidity of operation, it is far superior to hand application as it enables the operator to apply successive coats of paint more evenly, and to penetrate into places inaccessible to the brush.

Although it is true that a more durable finish can be imparted by using enamels, which dry and harden in an oven working at a relatively high temperature, these enamels are usually sprayed on from a gun; cycle frames, however, are generally dipped in the enamel and left to drain before stoving to avoid what are known as " runs."

Manufacturers of motor cycle engines favour stove enameling such parts as cylinder castings before any machining is undertaken; this practice not only protects the castings, but also prevents the absorption of oil by the metal, which is detrimental to the final finishing process.

Spray painting is therefore a most valuable process in the small shop for finishing its products, quite apart from its application to stove enamelling.

If spray painting on the commercial scale is intended, it will probably be profitable to consult a firm specializing in the production of apparatus for this purpose. On the other hand, it should be within the capacity of the small shop to

make all its own equipment, and, in this connection, the lay-out used by the writers will be discribed in detail later in this chapter.

Before doing so, however, it is as well to consider the principles on which the action of the simpler spray guns is founded. The underlying principle is that of the injector used for pumping fluids, and the working medium in this case is compressed air.

With the spray gun we are not concerned with pumping a large quantity of paint from the container, but it is important

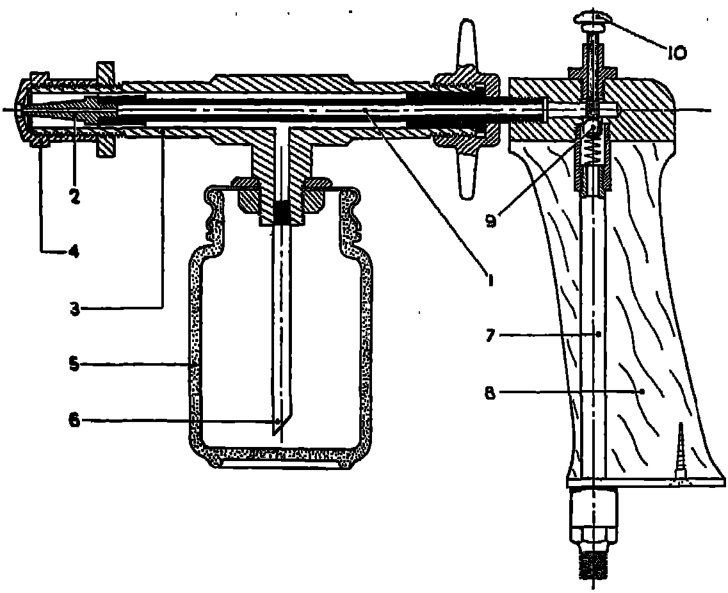


FIG. 1.

that the relatively small amount of paint ejected should be finely atomized by increasing the friction in the jet and its passages, rather than seeking to minimize this friction as in the case of the efficient injector designed for delivering large quantities of fluid.

Injector Type Spray Gun

Fig. 1 depicts a section of a typical spray gun which will serve to demonstrate the method of working.

Compressed air is supplied from the reservoir through the

pipe (7) which passes through the stock or hand-piece (8). At the base of this pipe a union is fitted for connection to the air line. At the upper end of the pipe (7) there is a ball valve which is operated by the button (10). On opening this valve, air is discharged along the pipe (1) and the jet (2) through the combining cone (4). This discharge of air at high pressure produces a partial vacuum in the space between the jet and the mixing tube (3). Any liquid in the reservoir (5) will therefore be drawn into the mixing tube by way of the pipe (6), and will be discharged with the air at the combining cone in a finely atomized state. The degree of atomization is governed by the pressure of the air, and consequently its resultant velocity at the combining cone.

By varying the relative distance between the jet and the combining cone, which is accomplished by adjusting the cone on its thread, the degree of lift can be controlled within fairly wide limits, thus varying the paint to air ratio.

This particular type of spray gun, which was designed by Mr. E. T. Westbury of the *Model Engineer* for use in the small shop, has been used by the authors with complete success for many years past. It is specifically intended for small work, and for jobs in which it will be in continuous operation until the completion of the work, for it is not possible to put the gun aside, for even a short time, without the danger of the paint tending to dry in the combining cone. This of course applies only to highly volatile paints of the cellulose type, and with oil-bound pigments this trouble does not arise.

Gravity Feed Spray Gun

If it is intended to carry out work which entails the gun being out of action for a time, a gun with a paint control valve in addition to the air control valve should be chosen. With a gun of this type, as depicted in Fig. 2, the paint is fed by gravity from the container (1) under the control of the valve (3).

The only functions of the air, in this case, are to atomize the paint and to distribute it over the work.

Air from the pipe line is fed to the gun by means of the union at the base of the stock, and thence through the pipe (5) under the control of the air valve (4). Both this valve and the paint valve (3) are operated by the trigger (2).

After passing the air valve, the air continues through passages machined in the body of the gun, into the space immediately

behind the combining cone. Thereafter, the action of the gun is similar to that of the injector type already described.

Air Supply System

Although it is possible to use a foot pump to supply air to the smaller sizes of spray guns, it is a practice not usually

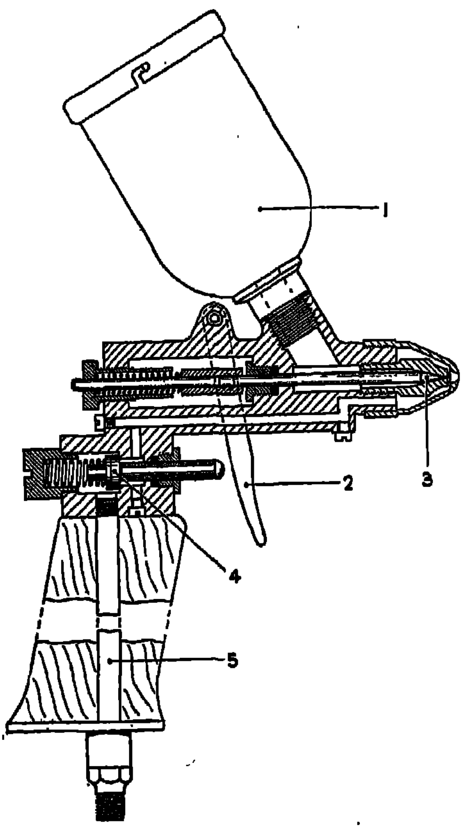


FIG. 2.

to be recommended, for human capacity is unequal to the sustained effort required to maintain an even air pressure which is essential for obtaining good results.

It follows, therefore, that to ensure satisfactory working a power-driven compressor must be installed, together with a suitable reservoir and the necessary air line fittings.

The installation here described has been used successfully for a number of years, and, while it has the merit of low initial cost, it is designed for intermittent rather than continuous operation.

As will be seen from the illustration of the general arrangement in Fig. 3, a compressor, driven by an electric motor or other source of power, supplies the primary air receiver, which is fitted with a drain valve, a monitor pressure gauge, and a combined safety and regulator valve.

From the primary cylinder the air passes through a non-return valve to the main receiver, which is equipped with

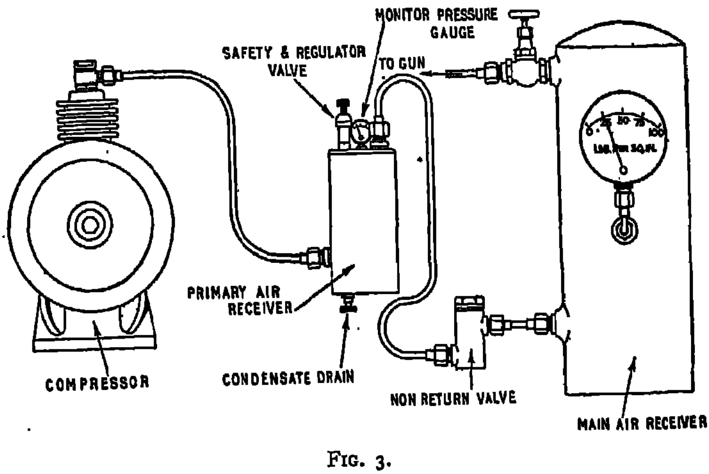


FIG. 3.

a large pressure gauge, and a screw-down delivery valve for controlling the air supply to the air line feeding the spray gun.

The installation was designed for a maximum working pressure of 100 lb. per square inch, but normally it is operated at 50 lb. per square inch.

The Compressor

The compressor used is one of the type which was formerly fitted to Buick cars for inflating the tyres.

These machines are well constructed and have a bore and stroke of approximately $1\frac{3}{4}$ in., which has proved adequate for supplying either of the two spray guns described, even when the compressor is run at relatively low speeds.

As these machines were of course designed for intermittent duty, the lubrication system is not elaborate; the piston picks up oil from a felt pad against which it impinges at the bottom of its travel, and the main bearings receive oil from a wick, which draws its supply of oil from a small reservoir cast in the crankcase, whilst the big end carries a graphitic oil-less bush which has given no trouble in service.

The compressor is usually run for an hour or more at a time, and the only modifications made to the lubrication system have been the fitting of a large oil cup to the main bearing reservoir, and replacement of the white metal crankshaft bearings by cast-iron bushes.

Attention is drawn to these points, as the reader may purchase one of these compressors as fitted to a car or commercial vehicle, and the modifications necessary to fit it for continuous duty should not be overlooked.

The fitting of a flywheel of adequate size is essential to ensure smooth running, and it should be borne in mind that it is wise to err on the side of providing excessive revolving weight in the flywheel rather than too little.

There is no need to go further into the question of the design and construction of the compressor, as there are several satisfactory commercial units available of a size suitable for use in the small workshop, and for those who wish to construct their own compressors, blue-prints and castings are generally obtainable.

The question of driving the compressor must be decided by the motive power available, but an electric motor with a drive either by chain or V-belt, affording the necessary reduction of speed, will be found most convenient for this purpose. It is essential that the speed for which the machine is designed should not be exceeded, otherwise overheating and lubrication troubles may arise which will reduce the machine's efficiency rather than increase its output.

In some circumstances a portable type of air compressor may be preferable to enable spray painting to be undertaken at a distance from the workshop, as, for example, when decorating the house or out-buildings.

Although these machines are equally well-suited for use within the workshop, if the exhaust gases are taken to the exterior by means of an extended exhaust pipe, the supply of compressed air may in addition be utilized further afield

for a variety of purposes, such as spraying fruit trees or inflating the car tyres in the garage.

The portable compressor made by the Hymatic Engineering Co. Ltd. and illustrated in Fig. 4 has been specially designed for portability and weighs but little more than 50 lb.

The motor and compressor are of unit construction with a crankshaft common to both machines. The compressor delivers its output to the tubular frame, which acts as both an air cooler and a water and oil trap; in addition, the frame is furnished with two drain cocks, and a union for coupling to the pneumatic accessories used with the apparatus.

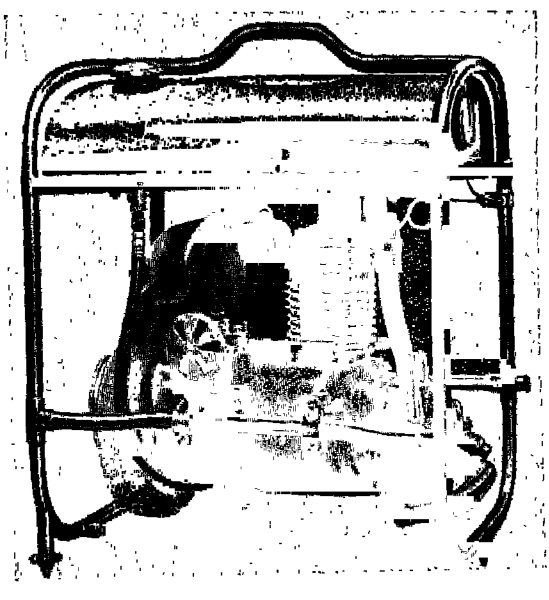


FIG. 4.

Messrs. Aerograph Co. Ltd. manufacture a rather more elaborate portable compressed air plant, provided with an air cylinder and mounted on a carriage equipped with two pneumatic-tyred wheels, as illustrated in Fig. 5.

In this case, the air-cooled petrol engine drives a two cylinder air compressor by means of a V-belt, and the volume of the output is adequate for spray painting on a commercial scale.

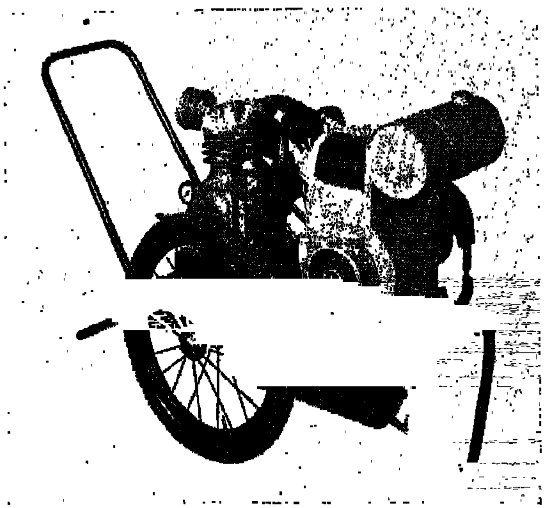


FIG. 5.

The Primary Air Receiver

The purpose of this unit is to trap any condensed water vapour, and to provide a relief device to enable the compressor to be started when the main receiver is partly filled. This is done by opening the regulator valve to allow the compressor to run without load, whilst the non-return valve, fitted between the primary and main receivers, will prevent any feed-back from the latter.

The working pressure of the installation is set by adjusting the regulating valve on the primary air cylinder until the monitor pressure gauge records the working pressure required.

Non-Return Valve

The use of this has been explained above, and any well-designed type of valve will be effective.

In the present instance, the simple spring-loaded cone valve shown in Fig. 6 is used, but as the valve seats itself by gravity, a spring is not essential. It should be noted that when a spring is used in this situation it should be made of phosphor-bronze, otherwise rapid rusting will ensue.

Main Air Receiver

It is advisable to instal a receiver of ample size, and any receiver so used should be capable of withstanding a working

pressure of 100 lb. per sq. inch following a preliminary hydraulic test of 200 lb. per sq. inch.

The receiver depicted is a water softener cylinder of robust construction, and carries a pressure gauge with a four-inch diameter dial which is easily read at a distance.

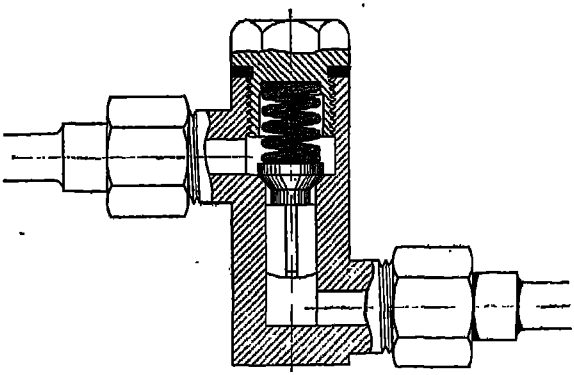


FIG. 6.

Piping

To ensure airtight joints and a neat appearance, ¼ in. copper tube with cone nipples and union nuts is used, but if several spray guns are used simultaneously, the size of the piping must be increased and iron tubing or steam barrel may be used to save expense.

Hose

The lightest hose that is capable of carrying the pressure hould be used, as this saves weight and consequent drag on the arm when painting.

Tyre inflator hose has been found excellent for the purpose, but the bore should not be less than about $\frac{5}{32}$ in. or the air supply to the nozzle may be restricted.

For commercial use lightness in weight will have to be sacrificed to gain mechanical strength and the ability to withstand rough usage.

Paint

This is a subject with which it is hardly possible to deal adequately in a short space.

Problems connected with the choice of suitable types of paint are best addressed to the manufacturers, as they alone can give authoritative advice on the subject.

Whatever class of paint is used, whether it be oil-bound, synthetic, or cellulose-base, its correct consistency is really one for individual experiment with the particular spraying apparatus used, but in general the thinner the paint the better. Too thick paint is not so liable to give bad results with oil-bound and enamel types, but in the case of cellulose paints, too heavy a consistency readily leads to the formation of a finish resembling orange peel, and runs and streaks may be formed on vertical surfaces.

Technique

In the space available it is possible to give only the barest outline of the procedure to be adopted in spray painting, and a correct technique will be learnt by experiment and practice, which can in nowise be replaced by written instructions.

Before the paint is applied the work must be perfectly clean and dry, and if there is any possibility of oil on the surface, a thorough cleaning with good quality petrol must be given. The form of the article will decide whether it should be painted standing on the bench or hung by a wire; in the former case, it is usual to place the work on a turntable, so that it can be moved round without handling as the work proceeds.

If the article is to be painted in a single colour, it is only necessary to observe the warning on cleanliness and to proceed with confidence, but at the same time taking care not to apply the pigment at too fast a rate, or an uneven surface marked by runs will result.

Should this occur, it is best to wipe off the paint with a rag soaked in "thinners," that is to say the solvent appropriate for the paint in use, and after this treatment the spraying should be started anew.

If, on the other hand, more than one colour is to be applied, the surface of the work must be masked in those places where the paint is not required. For small surfaces this may be done with adhesive tape, but, in the case of large areas, sheets of brown paper may be held in place by strips of adhesive tape applied to their edges.

Whatever type of spray gun is used, provision should be made for hanging it up on a hook when not actually in use, otherwise, the gun may be overturned and valuable and expensive paint spilt. Remember also that the gun is connected with several feet of hose, over which the operator may trip,

with resulting damage to the gun in addition to the loss of paint.

In the trade it is obligatory to carry out the work in a properly designed spraying booth, fitted with an extractor fan to carry away the highly injurious paint fumes.

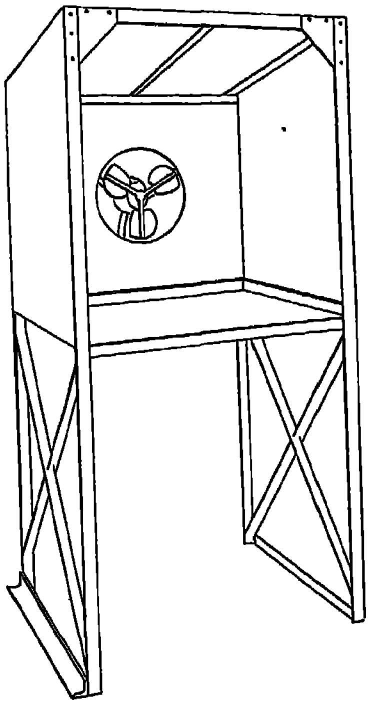


FIG. 7.

The fact that these fumes are injurious must be stressed, and even the small private shop-owner should consider the advisability of providing a small booth if much painting is done. Fig. 7 depicts a convenient type of small spraying booth equipped with an extractor fan.

When only occasional spraying for short periods is undertaken, it may be found satisfactory to do the work in the open air on a fine day, but within a small workshop the atmosphere quickly becomes overpowering.

No attempt to carry out spray painting commercially should be made until the legal position has been fully studied with regard to the Acts affecting the trade, and in addition, the Fire Insurance Company's views should be ascertained.

CHAPTER XII

MECHANICAL DRAWING

Drawing Equipment. The Draughting Machine. Pencils and Drawing Pens. Drawing Paper. Erasers. Drawing Ink. Drawing Conventions. Drawing to Scale. Projection Methods. Isometric Projection. Sectional Drawing. Drawings for Publication. Back-Lining. Shading Methods. Correction of Errors in Inked Work.

THE essential purpose of mechanical drawings is to represent the drawing office designs graphically and in readily understandable form to the engineering workshop.

To this end, these drawings are always made in accordance with a recognized and conventional system, and are in no sense artistic pictures.

In general, a set of drawings for any particular machine consists of one or more General Arrangement Drawings, which show the machine in full or part-section as may be required for intelligibility, and in addition a series of Detail Drawings in which each part of the machine is drawn separately and in detail. Accompanying these drawings is a Parts List on which is recorded the Reference Number given to each individual part. This reference table greatly facilitates the co-ordination of the subsequent machining operations.

From what has been already stated, it will be clear that machine drawings are severely utilitarian, and from the commercial point of view the valuable time of the drawing office should not be wasted in the production of unduly elaborate work.

For this reason, certain conventions, which will be described later, have been adopted to shorten and simplify the work of the draughtsman.

Drawing Equipment

In order to make satisfactory working drawings, the following equipment is usually regarded as essential:

A drawing board, of adequate size for the work undertaken, equipped with a T-square.

A pair of set-squares, one 10 ins. long with angles of 60 and 30 degrees, and the other 6 ins. with angles of 45 degrees.
A set of drawing instruments as specified below.
Scale rules. Pencils with hard lead—HHHH or HHH.
Erasers and Indian ink.

One or more French curves may be added for drawing curves difficult to scribe with compasses.

When selecting drawing instruments readers are warned against purchasing those of inferior quality, for it is more satisfactory, and in the end cheaper, to acquire in the first place a few necessary instruments rather than to buy a set of poor quality equipment.

The essential instruments are a pair of 4 in. dividers with needle points and furnished with additional pen and pencil points as well as a lengthening bar.

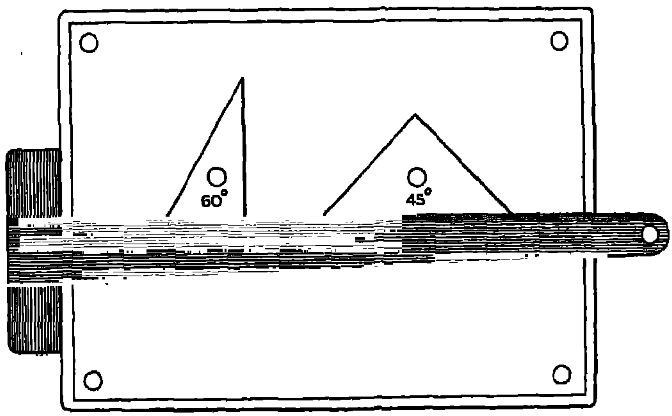


FIG. 1.

The scale rules should be of the open divided type, and should include the following scales:

6 ins.	to the foot	or	One-half full size.
3 ins.	,,	,,	One-fourth full size.
2 ins.	,,	,,	One-sixth full size.
$1\frac{1}{2}$ ins.	,,	,,	One-eighth full size.
1 in.	,,	,,	One-twelfth full size.
$\frac{3}{4}$ in.	,,	,,	One-sixteenth full size.
$\frac{1}{2}$ in.	,,	,,	One-twentyfourth full size.

Although the above equipment, which is depicted in Figs. 1, 2 and 3, will enable drawings to be made, it will be found

that with the compasses specified it will be difficult to draw very small circles, and for this purpose the purchase of a pair of

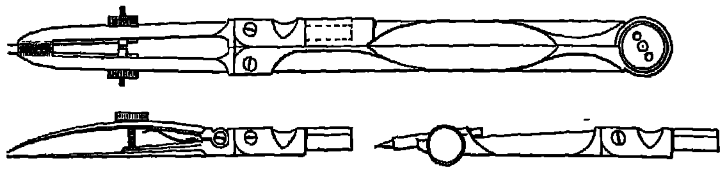


FIG. 2.

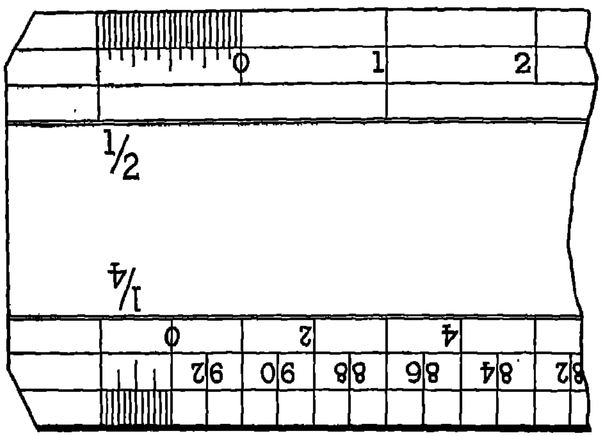


FIG. 3.

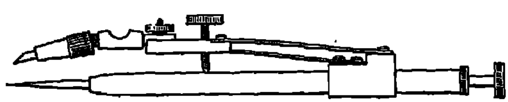


FIG. 4.

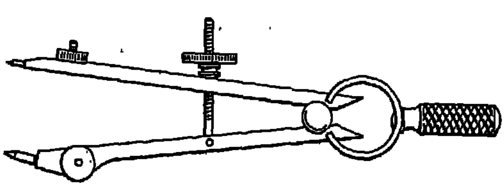


FIG. 4 (A).

pump-centre compasses as shown in Fig. 4 is advised. With these compasses small circles can be readily drawn, and, as they have both pen and pencil points, they supersede the small

spring-bow compasses shown in Fig. 4A which are made as individual units with non-interchangeable points.

In addition, the provision of a pair of 4 in. dividers as illustrated in Fig. 5, will be found useful for pricking-off centre points, and, moreover, the frequent changing of the compass points will thus be avoided.

Finally, to enable pencil work to be inked in it is necessary to use one or more ruling pens of the type illustrated in Fig 6. The employment of two pens allows one to be kept set for outline work and the other to be used for the fine lining of dimensional and centre-line drawing.

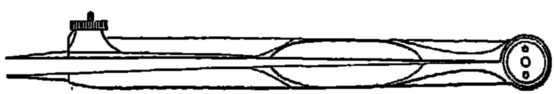


FIG. 5.

The Draughting Machine

One additional item of equipment has yet to be mentioned; this is the Draughting Machine which takes the place of the drawing board and T-square and is perhaps more convenient to use.

Although small set-squares may be used with the draughting machine, this is not essential as the protractor-head of the

FIG. 6.

machine can be set to any angle required and then locked in position.

As will be seen in the drawing in Fig. 7, the draughting machine is furnished with a protractor-head to which a pair of scales is attached, and by loosening the locking knob these scales can be moved round to any desired angle.

The whole device is anchored to the drawing board by means of a bracket, provided with an adjustable clamp for setting the scales to the zero position in relation to the board.

Attached to the clamp and to the protractor-head are two pairs of pantograph arms which have their inner ends located on a joint ring. The pantograph arms are free to move in a

horizontal plane, and are pivoted on tapered screws which can be adjusted to provide free but shakeless movement.

This arrangement of the pantograph arms constitutes a pair of parallelograms, whose equal opposite sides are coupled together at right angles on the joint ring.

The geometric construction of such device ensures that an object, such as a set-square, attached to the arms will maintain its relative angularity wherever it is moved on the surface of the drawing board.

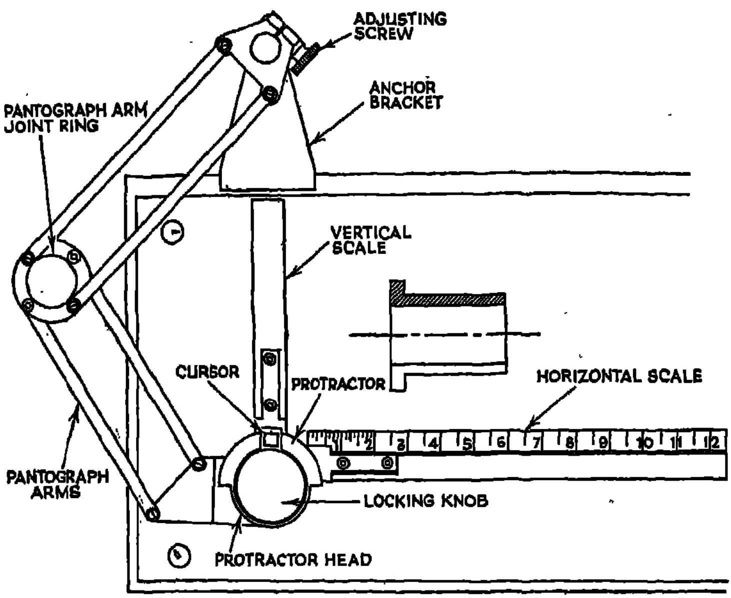


FIG. 7.

In the case of the draughting machine, the protractor-head is the object in point, and the scales attached to it will each trace parallel lines irrespective of the angle to which they are set.

The illustration shows a machine actually constructed which has given excellent service, and all the line drawings included in this book have been made with its aid.

Pencils and Drawing Pens

Pencils of the hard variety should be purchased, for soft pencils wear down quickly and in that condition will not form the fine lines essential in machine drawing.

Pencils may be sharpened either to a needle point as shown in Fig. 8a, or to a chisel edge as in Fig. 8b.

The latter form is preferable as it facilitates ruling lines and in addition maintains its edge longer.

A piece of glass-paper attached to a wooden block may be used for sharpening the lead and for finishing the point of the pencil, but if desired a fine file may be employed for this purpose.

Best quality drawing pens usually have a hinged blade which can be fully opened for cleaning, or for sharpening the pen on an oil-stone when it has become worn by the slightly abrasive action of the drawing paper.

Wear of the pen point will interfere with the ruling of fine lines, for in this case a fine smooth pen is required, and any

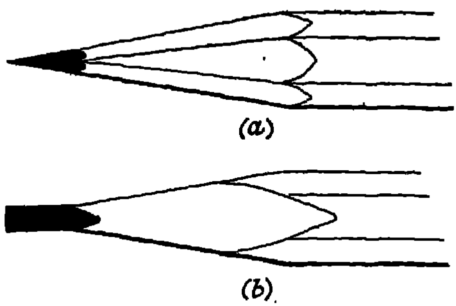


FIG. 8.

roughness of the edge may cut into the paper and produce a ragged line.

To sharpen the drawing pen, screw the nibs together and, with the pen held vertically to ensure that the nibs are maintained of equal length, move it lightly to and fro on an oil-stone with a rocking motion to produce a slightly rounded point. The nibs are then opened and each is sharpened on its outer surface to thin the points equally.

The nibs should not be stoned on their inner surfaces, but any burrs present should be carefully removed on the oil-stone.

The ruling pen illustrated in Fig. 6 is a type which has come into general use, largely on account of its being cheaper to produce than the folding blade variety.

The construction of the hinged blade form can be seen in the illustration of the compass pen point shown in Fig. 2.

Drawing Paper

The best type of paper for use in making mechanical drawings is a hot-pressed paper of Whatman character. This is a fairly heavy paper with a smooth surface which gives clear pencil reproduction, and is particularly suited to finishing drawings in Indian ink.

For making small drawings, on the other hand, a good quality typing paper is quite satisfactory, and, owing to its convenient size, it is useful for drawings intended for reproduction in the Press.

The standard sizes of paper and the names by which they are known are as follows:—

Medium	Imperial	Double Elephant	Antiquarian
22 in. × 17 in.	30 in. × 22 in.	40 in. × 27 in.	52 in. × 31 in.

This by no means represents all the available sizes but includes those most commonly used.

In commercial drawing offices it is customary to make drawings directly on tracing paper, as such drawings are then ready as negatives from which copies can be printed for use in the engineering shops.

In order that the draughtsman may obtain a clear view, he attaches a sheet of what is known as backing paper to the drawing board prior to pinning down the tracing paper.

It will also be found that the use of a backing paper with any type of drawing paper will greatly facilitate the work.

Erasers

Three erasers should be provided for use when making mechanical drawings; the first for rubbing out pencil lines, the second of larger size for cleaning the whole drawing after inking-in, and the third an ink eraser for removing Indian ink.

When using the ink eraser it is necessary to follow it with the ordinary pencil eraser to restore the smooth surface of the paper and allow ink again to be used.

In making drawings for reproduction in the Press other methods of correcting errors may be used, and these will be referred to later in the chapter.

When removing errors of drawing with the ink eraser, lines in the vicinity should be protected from damage by means of a thin sheet steel mask.

Drawing Ink

For all inking-in work Indian ink alone is used, although formerly it was customary to use red ink for centre lines, but as this difference of colour is not reproduced in the printing process, this practice has now been abandoned.

Indian ink, although waterproof when dry, is readily soluble in water and should be used well diluted to ensure that it flows freely in the ruling pen, but if it is over diluted it loses its waterproof properties, and can then be easily removed with the pencil eraser.

Drawing Conventions

Earlier in this chapter mention was made of certain conventions practised in machine drawing to enable the drawings to be readily interpreted, and also to facilitate the work of the drawing office.

These conventions relate, in particular, to the representation of centre lines, lines to indicate dimensional points, and lines to show the outline of a component which is hidden in the actual view drawn. In addition, the drawing of screw threads and of nuts and bolts has in this way been greatly simplified.

Centre Lines. These are represented by a broken line as shown in Fig. 9 (a) and indicate the axis of a component.

If the drawing represents the general arrangement of a complete mechanism, the centre lines of all major components as well as bolts, studs and screws should be shown.

Centres of shaft ends and bores seen end-on are indicated by two lines at right angles, as is shown in Fig. 9 (b).

Dimension Lines. In order to show dimensions on drawings, lines are projected at right angles to that part of the drawing where the indication is required, and a single line with an arrow-head at either end is then drawn to join these lines at right angles. The arrow-headed line has the dimension figures marked on it as shown in Fig. 9 (c).

Dimension lines should always be made thinner than the outline of the drawing itself.

Covered Lines. It is often necessary to indicate the outline of some part on the opposite side of a drawing which is hidden from view; this is done by using dotted or broken lines.

The same procedure can be used to indicate holes drilled in a solid object as is seen in Fig. 9 (a).

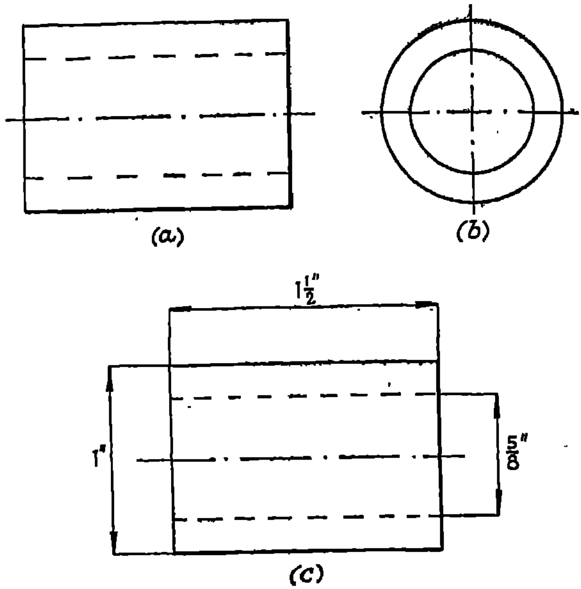


FIG. 9.

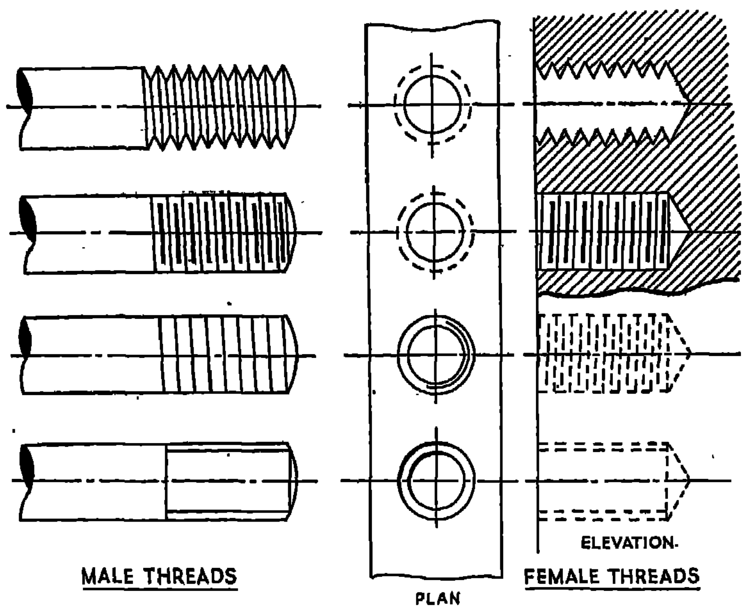


FIG. 10.—Conventional Methods of Depicting Screw Threads.

Screw Threads. If it were necessary to draw in detail all the screw threads which appear in mechanical drawings, it is clear that much of the work would be most tedious for the draughtsman, quite apart from the waste of time involved.

It has therefore been found expedient to simplify this work, and Fig. 10 shows the different conventional methods used for depicting screw threads.

In the case of drawings intended for reproduction in books or catalogues, more elaboration is advisable to gain a good

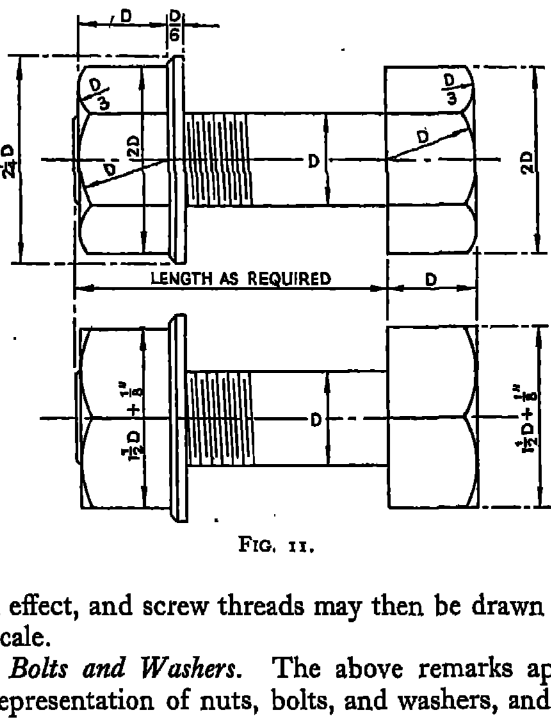


FIG. 11.

pictorial effect, and screw threads may then be drawn in detail and to scale.

Nuts, Bolts and Washers. The above remarks apply also to the representation of nuts, bolts, and washers, and Fig. 11 shows the correct proportions of these when an academic style of drawing is used.

Drawing to Scale

It often happens that a drawing has to be made of an object that is too large for reproduction at its full size, and resort must then be had to drawing it to some convenient scale. The scale adopted should always be indicated on the drawing as a guide to the actual size of the object represented.

Earlier in this chapter a table was given of the scales in common use, and a portion of a typical scale rule is shown in Fig. 3.

To use the scale it is only necessary to set the dividers to the required dimension as shown on the scale. and to transfer this to the drawing board.

Formerly, best quality scales were made of ivory or boxwood, but now ivorine scales are more generally used and are excellent for their purpose.

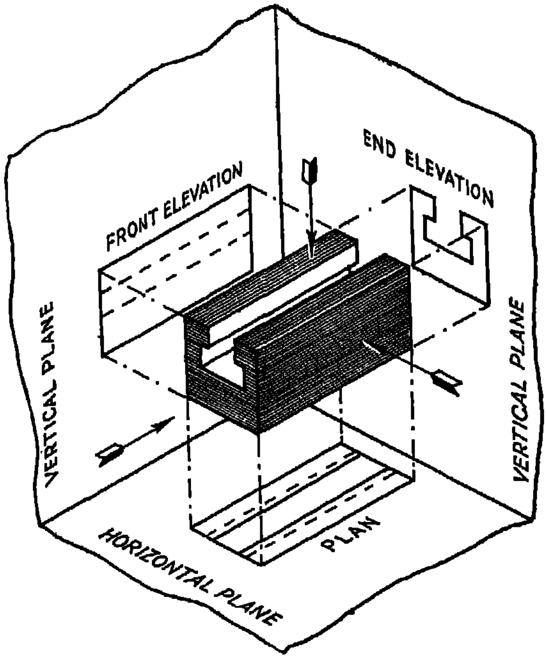


Fig. 12.

Projection Methods

As an aid to the interpretation of drawings it is customary to present views of the object in the three planes in space; that is to say, a plan view as seen from above, a front elevation and an end elevation, representing the front and end views of the object respectively.

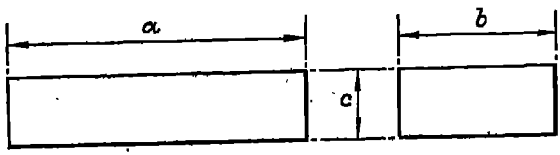
These methods of delineation are set out graphically in Fig. 12.

In engineering drawing offices there has been a considerable

difference of opinion as to the correct method of projecting one view from another, but it is now generally agreed that the following method is the most satisfactory: the projection of an end elevation, when looking from the left, is placed to the right on the front elevation, and the plan view is placed below the front elevation; it will be appreciated that this scheme is in accordance with the arrangement seen in Fig. 12.

Isometric Projection

This form of projection has been termed the perspective of the drawing office, but in point of fact it is not concerned with perspective.



DRAWING OF RECTANGULAR BLOCK NECESSITATING TWO VIEWS

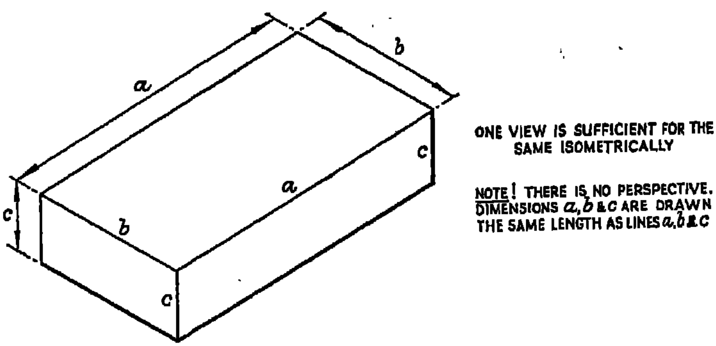


FIG. 13.

This method enables the draughtsman to dispense with elevations and to combine in one view all the information necessary for the interpretation of a drawing.

Isometric drawings depict an object as seen cornerwise by the viewer and presented in solid relief, but no attempt is made to introduce perspective into the drawing, for all related parallel lines are drawn of equal length irrespective of whether they are near to or at a distance from the viewer.

Fig. 13 shows a typical isometric drawing which demonstrates

clearly the principles involved, and it will be seen that all the horizontal lines of the normal elevation view are here drawn at an angle of 30 degrees to the horizontal.

Sectional Drawing

It will be apparent that, in machine drawings, the showing of mechanisms or their components in section offers a simple solution of the problem of making drawings readily intelligible, without unduly increasing their number or complexity.

Sectional views are therefore of great utility, and are generally a representation of the object as seen cut through on its

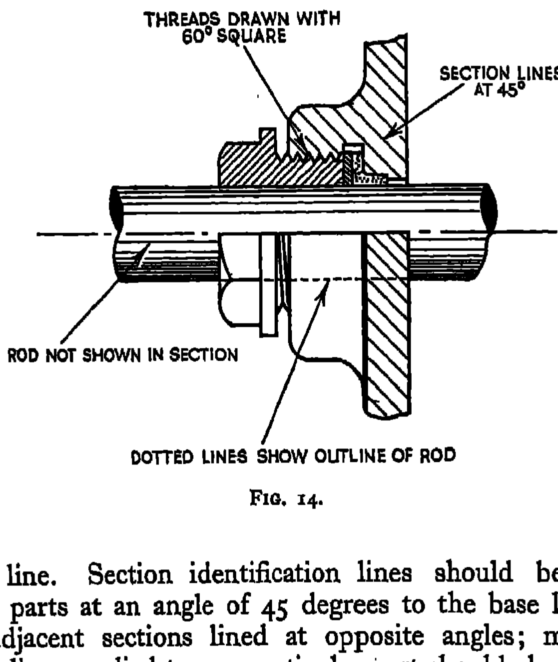


FIG. 14.

centre line. Section identification lines should be drawn on the parts at an angle of 45 degrees to the base line, and with adjacent sections lined at opposite angles; moreover, section lines applied to any particular part should always slope in the same direction in all drawings in which that part is represented.

Examples of section lining are shown in Fig. 14.

When, as sometimes happens, lining adjacent components at 45 degrees would cause confusion, the employment of lines at 30 degrees is permissible

Thin sections may also be lined at 30 degrees to increase

the length of the shading lines, but in this case a neater appearance is usually obtained by inking-in in solid black.

When drawing sectional views, items such as rods, bolts and studs are never sectioned unless there is some particular detail of their construction which makes this necessary. The numerous examples of sectional drawing that appear in this book may serve as a general guide to the accepted procedure.

Drawings for Publication

In general, these may be classed as machine drawings and artistic representations, but only the former category need be considered here.

When required for publication, machine drawings can be embellished by processes of back-lining, shading, and detail representation of screw threads.

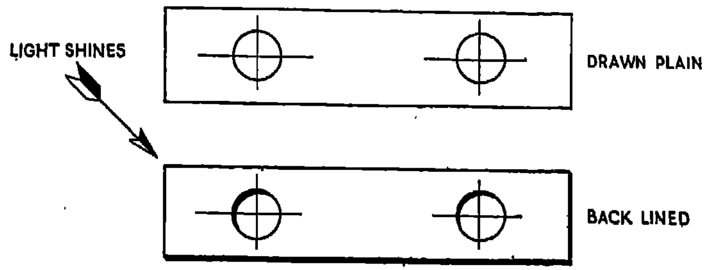


FIG. 15.

Back-Lining

This procedure is often adopted and it readily affords an excellent light and shade effect.

An example of this type of inking is shown in Fig. 15, and it will be apparent that the light is assumed to shine on the object at an angle of 45 degrees from the top left-hand corner of the drawing. The surfaces on which the light falls directly are outlined by thin lines, whilst those that are in the shade are represented by thick lines.

Shading Methods

In considering the methods of shading a drawing it must be borne in mind, as has been mentioned, that the light is supposed to fall on the object represented from a point to the

left and from both above and in front of the draughtsman; consequently the darkest part of the object is not its extreme lower edge.

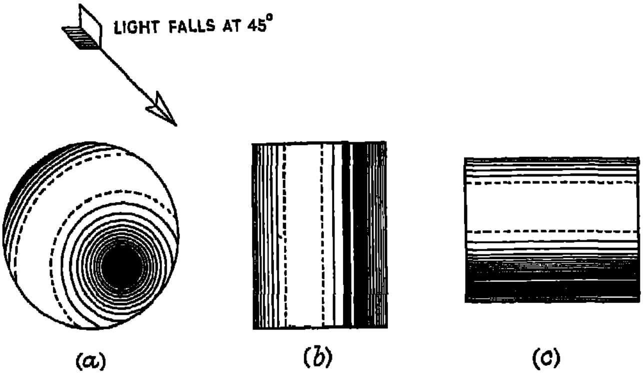


FIG. 16.

(*a*) Sphere. (*b*) Cylinder (vertical). (*c*) Cylinder (horizontal).

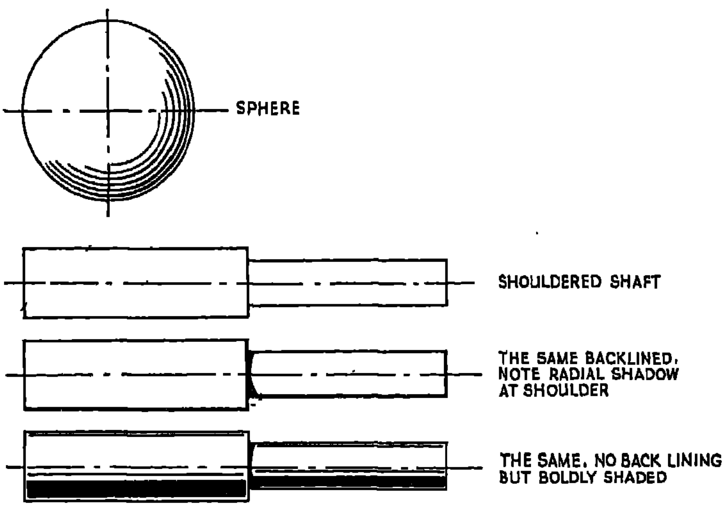
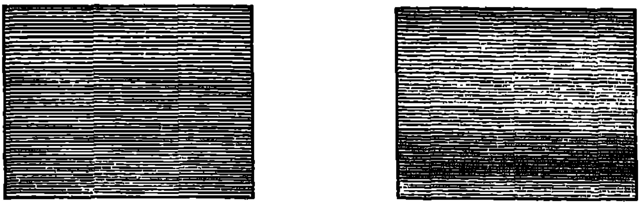


FIG. 17.

The usual methods by which drawings of different objects are shaded are shown in Fig. 16, although, for the sake of emphasis, in the examples depicted the shading is made unduly heavy.

Simpler methods of shading are shown in the drawings in Fig. 17, where a similar result is obtained, but the effect is, perhaps, preferable in the case of drawings intended for publication.

A method of shading that gives a good effect is shown in Fig. 18; here, thin lines are put in with very dilute Indian



(a) (b)

FIG. 18.

ink to produce a uniform shading effect, and the high-lights are then formed in any desired area by the use of an eraser.

For the detailed representation of screw threads, little can be added to what has already been mentioned earlier in this chapter, except to point out that a good effect can be

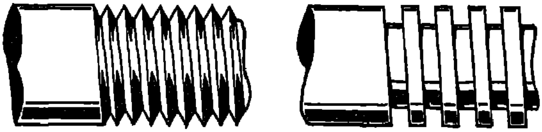


FIG. 19.

gained by shading as in Fig. 19, which illustrates a method of embellishing drawings of both V- and square threads.

Correction of Errors in Inked Work

If it can be avoided, no attempt should be made to remove errors with a rubber eraser, for the damage caused to the surface of the paper may cause difficulty if ink is again applied.

In the case of small errors it is preferable to obliterate the

ink by the application of a small quantity of Chinese White water paint, and for this purpose a wooden match sharpened to a chisel point may be used.

When dealing with more extensive errors, it is better to affix a piece of drawing paper or gummed paper over the unwanted area and then redraw as required.

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